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Geosat

The Geosat
Committee, Inc.

RECOMMENDATIONS CONCERNING SATELLITE-ACQUIRED EARTH RESOURCE DATA: 1982

REPORT OF THE DATA MANAGEMENT SUBCOMMITTEE OF THE GEOSAT COMMITTEE, INC.

November 1982

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SUMMARY

This report addresses end user concerns about the content and accessibility of libraries of remote sensing data in general. Most of the recommendations pertain to the United States' satellite remote sensing programs.

1. We urge that Congress and NASA take immediate steps to assure the continuation of the NASA/EROS Data Center program to convert pre-1979 scenes to computer-readable tapes and create a historical archive of this valuable data.

2. We recommend that the EROS Data Center archive of remote sensing data be improved by (a) the possible addition of new, geologically interesting scenes to the historical Landsat data base; (b) the inclusion of remote sensing data from other government agencies; (c) the adoption of a policy to retire data from the archive; and (d) the possible addition of previously classified data to the library.

3. We continue to recommend the establishment of a computer data base inquiry system that includes all remote sensing data from all publicly available sources.

4. We continue our call for a prepurchase data preview and evaluation capability.

5. We recommend the establishment of a realistic, flexible price structure for remote sensing data.

6. We recommend, where practical, the adoption of standard digital data products formats for U.S. and non-U.S. remote sensing systems.

7. We recommend that future government policies not preclude data pooling and data sharing by the users.

Appendices to this report include information about Landsat 4, the status of worldwide Landsat receiving stations, future non-U.S. remote sensing satellites, a list of sources for Landsat data, and the results of a survey of Geosat members' remote sensing data processing systems.

I. INTRODUCTION

In November of 1978 and again in December of 1979, the Data Management Subcommittee of the Geosat Committee, Inc., published reports (1, 2) representing Geosat's position on a number of points concerning the usability of U.S. government agency remote sensing data. Most of these recommendations were directed toward the Landsat program, which at that time involved the National Aeronautics and Space Administration's Goddard Space Flight Center together with the Department of the Interior and the EROS Data Center (EDC).

Much has changed since the first two reports. The National Oceanic and Atmospheric Administration has been designated the responsible agency for all Landsat operational activities. The current era of tight budgets for the government introduces more uncertainty for the users of remote sensing data who fear that necessary programs and needed improvements are in jeopardy. Finally, there is a growing number of non-U.S. remote sensing satellite programs that will probably greatly expand the quantity and the types of coverage available.

Despite the changes in the world of remote sensing and their potential effects on the user community, the concerns expressed by the Data Management Subcommittee remain. For these reasons, we feel that it is timely to reassess the concerns of our segment of the consumers of remote sensing data and, where necessary, attempt to provoke responses from those who could solve the problems that we identify.

The recommendations from the first two reports are summarized along with comments about progress toward implementing them:

Recommendation	Status
1978	
1. Establish a central inquiry system for all government-acquired remote sensing data.	1. Catalogs of individual data bases exist. They are not in form of a computer inquiry system. They are not comprehensive. They do not contain desired attributes.
2. Centralize distribution of remotely sensed data.	2. Done for Landsat. Other information requires dealing with archiving agency.
3. Establish enhanced film products and raw data CCTs as primary Landsat data products.	3. A-format data available for Landsat.
4. Implement format and distribution media associated with EDIPs.	4. Done.
5. Establish formal, structured channels of communication and feedback between users and responsible government agencies.	5. Not formal or structured.

Recommendation	Status
6. Establish board to advise government agencies in plans for remote sensing data.	6. Done with NOAA advisory board.
7. Establish a "quick look" data review facility.	7. Data preview available in microform library at EDC.
8. Make one agency responsible for interfacing with users.	8. NOAA responsible for Landsat, but other agencies are involved for other programs.
9. Permit users to request special coverage by satellite system.	9. Implemented.
10. Acquire complete global, cloud-free coverage for distribution.	10. Progress made, but not complete. No further work planned.
11. Associate latitude and longitude with satellite data.	11. Done for Landsat.
1979	
1. Central inquiry system.	1. See 1978, No. 1.
2. Investigate reclassifying data from secret systems.	2. No success in achieving reclassification.
3. Maintain NDPF systems at GSFC to complete conversion of pre-1974 Landsat 1 scenes.	3. System deteriorating; data not converted completely. Future of system is uncertain.
4. Develop software in GSFC-IPF system to process tapes from Landsat 1 and Landsat 2, April 1974 to November 1976, to HDTs.	4. No plans to convert to HDT, only CCTx.
5. Set up digital communication link between NASA/GSFC and EDC for TM data.	5. Will have to rely on CCTs via ground transportation.
6. Quick look facility.	6. See 1978, No. 7.
7. Establish an EROS advisory board.	7. NOAA advisory board fulfills this need to some degree.

From these, one can see that EDC and NASA have made progress in meeting user needs for Landsat data. The interface between EDC and the user community has been an especially successful one. EDC usually meets user requests in a timely manner, and their Landsat Data User Notes are valuable sources of information to the user community. However, the recommendations concerning a universal data inquiry system and that of a data preview capability are still unanswered (see Section V following for a definition of this term). Little has been done to insure that no useful data are being lost as time erodes our ability to convert image and telemetry data from Landsat 1 and Landsat 2. The present budget and economic situations threaten users of Landsat data who need assurances of the timely flow of great quantities of data. The future development of non-U.S. and private remote sensing activities will likely exacerbate user ignorance of what is available and from whom.

If we can make the fundamental assumption that there will be a continuing and preferably improving source of satellite remote sensing data, user concerns about remote sensing data fall into five major categories. First, they want to know what information coverage is available and would like to gather data if none exist. Then a rapid, usable assessment of the quality and usefulness of the coverage should be possible. Obtaining the desired coverage should not be unduly complicated, time-consuming, or costly. Data archives should be maintained so that unique information is always available. These three concerns would be addressed by a general data library facility. Many data users also have requirements for rapid response from the data library; others need assurance of continuity in its existence and an orderly development of its operations.

Because of our concerns, we make the following recommendations:

1. Because of the possibility of finding unique coverage, we applaud the NASA/EDC program to augment the historical data base from the period 1972 to 1976 with approximately 30,000 scenes. We urge NOAA, EDC, NASA, and Congress to take steps to avert the premature termination of this potentially valuable program.

2. It is important to implement a program for preserving and archiving in accessible form as much useful remote sensing data as possible.

   a. A committee of users should be convened to identify unique, useful scenes pre-1979 from archived Landsat wide-band video tapes and determine the priority for conversion to archive format by government. The government should then commit to the conversion.

   b. A central archiving facility for all remote sensing should be established as a more useful and more cost-effective alternative to a number of different archives.

c. A reasonable archiving policy should be adopted which preserves unique data and retires data that are no longer useful.

d. A definitive answer on the eventual reclassification of any data from classified remote sensing systems is needed.

3. Some organization (government, private, or nonprofit corporations) must assume responsibility for and develop a plan for a complete computer data base inquiry system for all government remote sensing systems to permit users to determine what data coverage is available for a given geographic location and where it can be obtained.

4. A prepurchase data preview and evaluation capability would be very useful to the user community.

5. Flexibility in the pricing structure of remote sensing data should be defined to provide both fast response with a commensurate cost increase and a low-cost product that is affordable for educational purposes.

6. Adopt, where practical, the new EROS Data Center Landsat MSS computer-compatible tape format, Version 1.0, for other satellite digital data.

In this report, we will discuss each of the recommendations in turn. Included as appendices are information about present and future satellite remote sensing programs, the results of surveys of Geosat members' image processing equipment, and a listing of software resources for remote sensing.

II. THE HISTORICAL DATA BASE

The deterioration of the ephemeris data tapes and the special computer system for creating CCTx format tapes from early Landsat operations has prompted NASA and EDC to select potentially useful scenes for conversion to CCTx format and inclusion in a historical data base. These scenes were selected by EDC first on the basis of overall cloud cover (less than 30 percent) and then in an attempt to obtain seasonal* coverage worldwide. Approximately 30,000 scenes were selected for conversion covering the period from January 1972 through December 1976. Conversion has been proceeding at a rate of 150 scenes per week. NASA completed work on 1972 data in October 1982.

Personnel at NASA/Goddard are now working on scenes from 1973. However, publicity surrounding NASA's retiring the 1972 data tapes

*Four times per year in temperature climates, one time per year in tropical regions, and two times per year in transition areas.

has led a number of organizations, including the Geosat Committee, to request that NASA defer the destruction of the 1972 data tapes. In any event, the present Goddard timetable will require 4 years to complete unless additional funding is made available. With more funding, the production of CCTx's could double.

Despite the laudable effort of NASA and EDC to identify, convert, and save significant quantities of potentially valuable data, the outlook is not good. NASA has no budget to continue the data conversion program beyond September 30, 1983. Once the program is canceled, it is very likely that the unconverted data will be lost forever. To the geologist, this is especially significant for reasons: (1) Coverage of new, non-U.S. areas where weather hampers observation will probably be needed in the future. A large data base gathered over a period of time would be useful. (2) Coverage at different times of year and under different conditions is proving more and more useful to geological interpretation of remote sensing data. (3) The time to acquire new data or to proceed with the conversion of old is usually incompatible with that for making commercial decisions.

Therefore, we feel it is important that the Goddard Space Flight Center be permitted to continue adding to the historical archive as long as this is improving the quality of the EDC data base.

III. DATA ARCHIVES

A. ADDITIONS TO THE HISTORICAL DATA BASE

Since before the first Data Management Subcommittee report, it was apparent that large amounts of data from Landsat 1 and 2 prior to 1976 were not being converted to CCTs because NASA lacked the resources to do so. This situation has not changed. The principal reasons for wanting to examine these data are (1) the possibility of finding unique coverage, (2) the possibility of finding unusually good conditions in regions with a great deal of cloud cover, and (3) the possibility that future mission plans might not be carried out.

We propose that a subcommittee of Geosat members who use remote sensing data be formed to review the EROS Data Center recommendations for the historical data base and make any needed additions based on our present understanding of geological problems. This committee should be formed immediately and be prepared to complete its work before April 1983.

B. CENTRAL ARCHIVING FACILITY

Since many government agencies maintain their own libraries of remote sensing data, users must spend a great deal of time learning how and where to obtain information.

Moreover, it is likely that not all archives are being maintained with the needed care to prevent deterioration. Therefore, it seems prudent for the government to take steps to centralize the data archives for all publicly available remote sensing data.

C. NEED FOR A POLICY

The committee recommends that a data-archiving policy be initiated which protects both the user and the archivist. The Data Management Subcommittee should work with the archiving agency (i.e., EROS Data Center) to set up such a policy in 1983, which will serve as a basis for greater user/EDC cooperation.

The committee recognizes that at some point, not all the data acquired by the Earth Resources Observation Systems can be stored indefinitely and in user-retrievable condition. The length of time data should be stored, the storage form and medium, and the maximum manageable volume of data are items that require additional discussion. The point is made that at some time in the near future, data will have to be selectively archived due to physical space limitations, budget and manpower constraints, and data "shelf life." At the present time, data are being stored as shown in Table 1. It is universally agreed that some basic data set must be permanently preserved to serve the widest possible user community.

TABLE 1

STATUS OF ARCHIVED DATA PRODUCTS

(COURTESY OF S. FREDEN, NASA/GSFC)

July 1972 to Nov. 1976	Nov. 1976 to Jan. 1979	Jan. 1979 to Present
1. 70-mm film chips	1. 70-mm film chips	1. HDT-P or A and 241-mm film
2. WBVT in storage	2. WBVT in storage	
3. CCT-X available on request or through historical data set (no funding to continue with conversion after FY83)	3. Data can be converted to HDT or CCT-X (no decision about historical data set)	2. CCT-P or A available on order

The committee recommends that the selection of remotely sensed data to be permanently archived should be done recognizing the following points:

1. Data are taken and preserved on a lifetime based on anticipated need and modified by actual use.

2. The problem exists of exactly what data should be saved. Specific data products are of interest to only a limited number of users, and conversely, it can be argued that most (if not <u>all</u>) data products could be of some use to some users. The principle of diminishing returns applies; the data base should serve the greatest possible number of users within the identified constraints of storage capacity and shelf life.

3. Neither EDC, NASA, nor any single user group can adequately identify or select data for retention or destruction.

4. The archivist, EDC, has an obligation as a publicly funded entity to solicit advice from knowledgeable representatives of all the major users of remotely sensed data, including, at a minimum, representatives from federal agencies, universities, private industry, and service companies. Points of contact should include the Land Remote Sensing Satellite Advisory Committee (R. J. Keating, Committee Executive Director), the Geosat Committee (F. B. Henderson, III, President), and others selected to adequately represent the range of scientific disciplines using remotely sensed data.

5. The user should pay some archival costs, but this cost should impact most directly the groups requiring the greatest quantity of archived data. The establishment of a basic data set should be pursued in light of recommendations offered by the users. User groups requiring data archives in excess of the basic (historic) data set should be asked to pay a proportionately greater portion of the cost. One could accomplish this by establishing a two-tiered pricing structure, where products external to the "basic data set" would be priced higher.

IV. CENTRAL INQUIRY FOR ALL GOVERNMENT-ACQUIRED REMOTELY SENSED DATA AND THE DISTRIBUTION SYSTEM FOR THOSE DATA

A. REVIEW OF PAST SUBCOMMITTEE RECOMMENDATIONS

In the first Data Management Subcommittee report, issued in November 1978, it was recommended that "a centralized inquiry system for information regarding all government-acquired remotely sensed data and ultimately a central archival and distribution system for remotely sensed data be established." It

was pointed out that there was a considerable body of data acquired by various government agencies which might be of use in a wide range of applications if only people were aware of its existence and of how to access it. With wider usage of existing remote sensing data, it would become easier for government agencies to recommend and support appropriations for additional funding of space vehicles.

In its second report, issued in December 1979, the subcommittee again called for a centralized inquiry system. In the year after the first report was issued, little progress was made toward implementing this system. It was recognized that such a system was a long-term project requiring special funding. Therefore, it was suggested that as an interim solution, a listing of agencies which have such data available should be compiled along with the types of data and the methods for procuring it and determining its aerial coverage. Several agencies had published bulletins along these lines, but the data were scattered and it was difficult to find out what data were available without contacting each individual agency. The National Cartographic Information Center (NCIC) was recognized as the only agency attempting to unite other sources by maintaining a computer library of all USGS data as well as many state and private sources of remotely sensed data.

B. PRESENT STATUS

The goal of a central inquiry system has obviously not been achieved in the three years since the last subcommittee report. But there has been some progress in that direction. The EROS Data Center provides a list titled "Sources of Remote Sensing Data," in which it provides a description of a number of government agencies and the types of data each one has available. The list is very general in nature, but it does give addresses and phone numbers of the agencies involved to make it easier to access the data of interest.

A number of agencies publish their own catalogs, but these are not widely distributed. The NCIC still provides the closest approach to a central inquiry system. It operates a computerized indexing system which lists the holdings of many federal agencies as well as state agencies and some private sources. This system points the user to the source of a particular type of data, but the user still must contact the holding agency to acquire the data. The federal agencies which have data included in the listing are:

1. U.S. Geological Survey (USGS).
2. National Oceanic and Atmospheric Administration (NOAA).
3. Agricultural Stabilization and Conservation Service (ASCS).
4. Bureau of Land Management (BLM).
5. National Archives and Records Service (NARS).

6. U.S. Forest Service.
7. Library of Congress, Geography, and Map Division.
8. Soil Conservation Service (SCS).
9. Tennessee Valley Authority (TVA).
10. Department of Defense (DOD).
11. U.S. Corps of Engineers (USCE).

The EROS Data Center provides the closest approach to a single source of remote sensing data. It archives Landsat data as well as much of the data from Skylab, Apollo, and Gemini missions. Most of the NASA-sponsored high-altitude aerial photography is cataloged and stored at EROS as well as USGS conventional aerial photography and a considerable amount of aerial photography from the following agencies:

1. Army Map Service (AMS).
2. Air Force.
3. Navy.
4. Bureau of Land Management.
5. Bureau of Reclamation.
6. Wallops Flight Center (NASA) (Chesapeake Bay Ecological Program).
7. Marshall Flight Center (NASA).
8. U.S. Corps of Engineers.
9. South Dakota State University.
10. Mississippi Test Facility (NASA).
11. University of Michigan.

The chief problem is that with the exception of the Landsat data, the user never is guaranteed that there are not other useful, available data still in the possession of the providing agency. Therefore, the user must go to the holding agency to ensure that he is aware of complete coverage of a particular area. The advantage of using the EROS Data Center is that the coverage that it holds has been selected to provide what appears to represent the better-quality coverage of a particular area. Therefore, many users will find what they need by searching only at the EROS Data Center.

It would appear that at the time of this report, NCIC *is* the best hope for development of a central inquiry system. NCIC is receptive to and in the past has encouraged other agencies to provide the necessary information to catalog each agency's data. The main roadblock to providing such a comprehensive catalog resides in the individual agencies themselves. A particular agency, first of all, needs sufficient money to undertake the task of compiling the necessary information. It could safely be assumed that before an agency would request the funds, it would need an incentive to do so. It would require great expense and a monumental effort in terms of manpower for a particular agency to research its own data and compile a listing in a usable format for cataloging. The NCIC is ready

and willing to develop the software to convert an agency's format to that of the NCIC. So the particular format of a list is not as important as the actual development of a list. In the case of older data, the necessary geographic coordinates may be difficult, if not impossible, to establish. In addition, much of this data is not in machine-readable form and cannot be easily formatted. With respect to small amounts of data with very low user interest, the incentive to expend such a great effort may not be there. An interesting question is, then, how is user demand determined if most users do not know of the existence of the data?

C. FOR THE FUTURE

The Data Management Subcommittee still supports the concept of a central inquiry system for all types of remotely sensed data. At this time, the NCIC inquiry system seems to be the most complete. However, its separateness from the most complete data archive (EDC) is a potential problem. We recognize that a great deal of time and money will be needed to include old data in a central inquiry system. Therefore, we encourage each individual agency to evaluate each of its data holdings in terms of quality, size, and demand in considering whether or not to provide the necessary information to the data base. Progress along these lines has been painfully slow, but with the continual encouragement of the user community, the process might be speeded up.

The subcommittee strongly recommends that any new data acquired by any agency should be recorded and stored with the necessary geographic information in machine-readable form for immediate listing in the data base. While the amount of money to reformat and list previously acquired data is substantial, that required to properly record new data is almost insignificant in relation to the overall cost of acquiring the data. If each agency recognizes its obligation to provide the proper information, the problem then becomes one of interagency cooperation rather than money.

V. DATA PREVIEW CAPABILITY

Regardless of specific user application, there is a need to evaluate the quality of Landsat images which are available for given geographical regions prior to ordering data products. Particularly when cloud cover is present over a portion of the scene, a numerical quality rating or cloud cover percentage is not adequate for selection of suitable imagery. As data prices increase, it becomes even more important that the user be confident that the highest-quality data available are being ordered. Price aside, a significant amount of time may be wasted if an image, upon arrival, proves to be unusable and a replacement image must be ordered. The only solution appears to be the provision of one or more ways of viewing

the images firsthand prior to ordering. At present, this can be done only by viewing black-and-white microfilms at the EROS Data Center, at NASA Goddard Space Flight Center, or at one of the several browse files scattered around the country.

One important aspect of the data preview issue relates to the time lag between scene acquisition and the user's viewing of a preview image. The present microfilm browse file system is updated quarterly, so several months may elapse before a scene is actually available for examination. Earlier recommendations by the Geosat Data Management Subcommittee were for a ". . . 'quick look' system to judge overall quality of data and specific coverage within 72 hours after an inquiry is made" (1) and ". . . minimally processed remote sensing data on paper or film distributed to him soon after the satellite data have been received at a receiving station" (2).

Present plans within NOAA and at the EROS Data Center include the production of a microImage microfiche series which will be keyed to the paths, rows, and zones of the Landsat Worldwide Reference System. It is anticipated that the fiches will be available about 18 days after scene acquisition; new packets of fiches will probably be mailed weekly. At least as originally planned, the 251 paths or ground tracks of the satellite would ". . . form the basis for identifying 10 'regions' covering the major land masses of the world. The 124 Rows, or lines of latitude intersecting the Paths, [would be] divided into three major 'zones' for the north, south and polar areas of the Earth" (Landsat Data Users Notes No. 5, March 1979). Users will be able to order microimage fiches for any zone or region individually or any combination thereof. A subscription service will be available from the EROS Data Center to keep user files updated as new fiches are produced. To make such a system feasible, a functioning TDRSS (Tracking and Data Relay Satellite System) must be operational. This is necessary in order to process and access the data in order according to path and row number. The TDRSS is scheduled to become operational during 1983.

In light of strong assurances from NOAA's Landsat Program Director and the chief of the EROS Data Center that the microImage system will become available as soon as technically possible, the Data Management Subcommittee has relaxed its position somewhat. We feel that while the 72-hour examination copies would be more desirable, the fiche images, if provided as quickly as described above, will provide a workable alternative.

VI. FLEXIBLE PRICING STRUCTURE

NOAA has targeted for a typical response time of 2 weeks from time of actual image acquisition to the distribution of film, paper products, and CCTs. This response time is generally adequate for geoscience applications. This "pipeline" approach has many advantages; however, some limitations exist.

First, users that need quick access to data--for example, one or two days--should be provided this access if they are willing to pay the price. This flexibility should enlarge the customer base and provide more revenue for NOAA.

Second, current prices will indeed eliminate access to data products for some users altogether. The university environment will be substantially affected. Off-the-shelf packages of imagery--both hard copy and digital--could be provided at a nominal cost. Although lacking in flexibility, these prepared data sets could address some of the educational needs.

The Geosat Committee recognizes the importance of maintaining a viable path between remotely sensed data and our educational facilities.

VII. DATA FORMAT

As indicated in Appendix C of this report, there is a growing number of remote sensing systems that will be producing data for the public worldwide. To avoid the inefficient situation in which a user would have to maintain different systems to use each type of data, we urge the agencies involved to adopt a single format. By virtue of its existence and worldwide acceptance, the EDC Landsat MSS computer-compatible tape format, Version 1.0, would be the obvious choice.

VIII. CLASSIFIED REMOTE SENSING DATA

Soon after its formation in 1976, the Geosat Committee became interested in the possibility that the civil satellite remotely sensed data base might be improved by data from the military sector. We have also recognized that future release of presently classified remote sensing data could lead to serious problems for private sector firms involved in the commercialization of civil satellite remote sensing data.

The Geosat Committee raised the possibility with members of the national security community of reclassifying, i.e., making available to our user community, some of its satellite remote sensing data. The committee contributed to two major studies conducted by the Carter administration. These studies led to Presidential Directive 54 (November 1979).

The two previous Data Management Subcommittee reports contained recommendations on the reclassification issue:

<u>November 1978</u>-"Recently, there has been a greater effort to determine if data is available in government files which is currently classified but could be released for public use. We applaud this recent effort and strongly encourage the declassification of as

much of this data as possible and make it available to the user community for evaluation."

December 1979--"The practicality of declassification of classified remotely sensed data should be evaluated by initiation of a pilot project in a limited geographic area. The pilot project would be useful in identifying methodologies for declassification in assessing the value of this data in locating critical natural resources."

As a result of the two reports, the committee continued discussing the issue with people in the intelligence community and particularly the National Security Council. A subcommittee of remote sensing geologists was formed by Geosat to review classified data. We proposed to the NSC to use the Geosat-NASA test case program sites to study the value of classified remote sensing data to our users. Up to now, however, there has been no official action by the government on our requests.

Although the change in administration in 1981 delayed resolution of the issue, the United States government is currently deciding what to do with both civil and military remote sensing data under Presidential Directive 54. The decision on civil data is to work toward commercialization. The government has articulated no policy on classified data and has made no response to our proposal for a study of classified information systems utilizing the Geosat-NASA test case sites. Should the Geosat Committee wish to participate in a study of the test case sites, we would have to actively push for it. It is unclear whether or not the government would be willing to cooperate. Further, we have no assurance that, even if classified data were to prove useful to our purposes, we would ever be given access to it. In fact, a positive study could have the opposite result.

While recognizing the complexity of the issue, the Data Management Subcommittee of the Geosat Committee wishes to reiterate how important it is that the U.S. government make a specific public decision on its policy regarding classified remotely sensed satellite data.

We remain ready to cooperate in a joint effort between industry and government to review the potential value of currently classified data for possible reclassification and public documentation. The joint Geosat-NASA test case program is now essentially complete; the sites would be particularly useful in a reclassification study. In addition, the Geosat Committee would welcome the opportunity to continue discussing the issues with people in government.

Therefore, the Data Management Subcommittee of the Geosat Committee recommends that the United States government, with the help of the Geosat Committee and others as appropriate,

1. Evaluate the desirability of providing reclassified or other currently unavailable government remotely sensed data to the growing civil satellite remote sensing data base.

2. As rapidly as possible, provide a clear and definitive public answer to the user community regarding the eventual reclassification of any data from classified remote sensing data sources and its eventual access and distribution to the user community during the next decade or beyond.

REFERENCES

1. Geosat Data Management Subcommittee Report, "Management of Satellite Acquired Earth Resources Data--Recommendations From the User Community," November 1978.

2. Geosat Data Management Subcommittee Report, "Management of Satellite Acquired Earth Resources Data--Part II," December 1979.

APPENDIX A

LANDSAT 4 DESCRIPTION

A complete description of Landsat 4 was published in Issue 23 of the Landsat Data Users Notes, a copy of which is included in this report.

LANDSAT 4

The Landsat satellites have been a valuable and prolific source of remotely sensed Earth resource data since the first Landsat was launched in July 1972. Although use of the data grew gradually at first, researchers made considerable progress in a relatively short time. As processing and information extraction techniques became more advanced, the application of Landsat data to practical problems in resource monitoring and management expanded greatly. Two more satellites were launched in 1975 and 1978, enabling this work to continue.

Today, 11 nations worldwide have the capability to directly receive and process data from Landsat. In addition, more than 100 nations now make serious use of Landsat data for resource evaluation and management. The practical applications of Landsat data are found in such activities as oil and mineral exploration, agriculture, land use monitoring and planning, forestry, range management, water management, and map making.

To date, however, the Landsat program has officially been an experimental effort. The same basic sensor package has been flown aboard the three Landsats orbited since 1972, and the methods by which the sensor data are transformed into user products, originally designed for research and development activities, continue to be time consuming and at times unreliable.

An operational, second-generation, Earth-sensing capability will be brought into use this summer after nearly a decade of developmental effort. This new system is known as Landsat 4, and it was launched on July 16, 1982.

The impetus for the Landsat 4 program came primarily from the recognition of certain limitations in the performance of the multispectral scanner (MSS) sensing instrument, the primary sensor aboard every Landsat since 1972. A new sensor system with improved spatial resolution, spectral separation, geometric fidelity, and radiometric accuracy was needed and therefore became the subject of a design effort initiated in the early 1970's. This effort has been in the execution phase since 1977. The second-generation, improved, Earth-observing sensor that emerged is called the thematic mapper (TM).

The TM relies heavily on the technology of the first-generation sensor, the MSS, but it achieves many improvements in capability which will add substantially to the effectiveness with which Landsat data can be used. A four-band MSS, similar to those flown before, is also carried on Landsat 4 and will collect data simultaneously with the TM. The two sensors, along with a vastly improved ground processing capability, will form a complete, highly automated data gathering system designed to serve the remote sensing community for the remainder of this decade.

Five major objectives for the Landsat 4 program have been identified by the National Aeronautics and Space Administration (NASA):

1. To assess the capability of the TM, and its associated ground systems, to provide improved information for Earth resources management.
2. To provide for continued availability of MSS data.
3. To provide a transition from MSS data to the higher resolution and data rate of the TM.
4. To provide for system-level feasibility demonstrations to define the characteristics of an operational land satellite system, including transfer of Landsat 4 management from NASA to the National Oceanic and Atmospheric Administration (NOAA).
5. To permit continued reception of Landsat data by other nations.

This issue of the Landsat Data Users NOTES includes a special review of the major elements of the Landsat 4 system.

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SPACECRAFT

The overall Landsat 4 system is considerably more complex than the Landsat 1, 2, and 3 systems (an exploded view of the spacecraft is provided on this page). Not only is Landsat 4's Earth coverage pattern different, but it is designed to interact with a number of other satellite systems for data relay, communications, and orbit control.

The observation platform is NASA's Multimission Modular Spacecraft (MMS), which provides power, altitude and attitude control, and onboard command and data handling. The MMS has an improved attitude-control capability over that of previous Landsat systems. The pointing accuracy is specified to be within 0.01 degree (1 sigma), and the stability is specified to be within 10^{-6} degree/second (1 sigma). These values compare with the 0.7-degree pointing accuracy and 0.01-degree/second stability associated with Landsats 1 through 3. In addition, the attitude control system information provided by the MMS is supplemented by an angular displacement sensor mounted on the TM. The angular displacement sensor provides the more precise information that may be needed to account for the effects of vibration (jitter) on the image data. The MMS is also designed for retrieval by the Space Shuttle.

Another major advance in the Landsat 4 system is represented in its capability to communicate with the new Tracking and Data Relay Satellite (TDRS) system which is scheduled to begin deployment in 1983. The TDRS vehicles will relay data from the satellite to Earth in near-real time, thus eliminating the need to rely upon onboard tape recorders, which have had limited lifetimes on previous Landsat missions.

The TDRS antenna located on the Landsat 4 spacecraft will permit command signals, telemetry signals, and TM and MSS sensor observations to be relayed, through one of the two TDRS satellites in geostationary orbit, to a single ground receiving station at White Sands, N. Mex. To handle the high data communication rates that are employed by Landsat 4, as well as other spacecraft served by TDRS, the TDRS system will use a Ku-band frequency for communications to the ground. This frequency will support simultaneous transmission of both TM and MSS data.

A domestic communications satellite (DOMSAT) system will be used to transmit sensor data from White Sands to the data processing facility at the Goddard Space Flight Center (GSFC) in Greenbelt, Md., and subsequently to the Landsat data distribution center at the Earth Resources Observation Systems (EROS) Data Center in Sioux Falls, S. Dak.

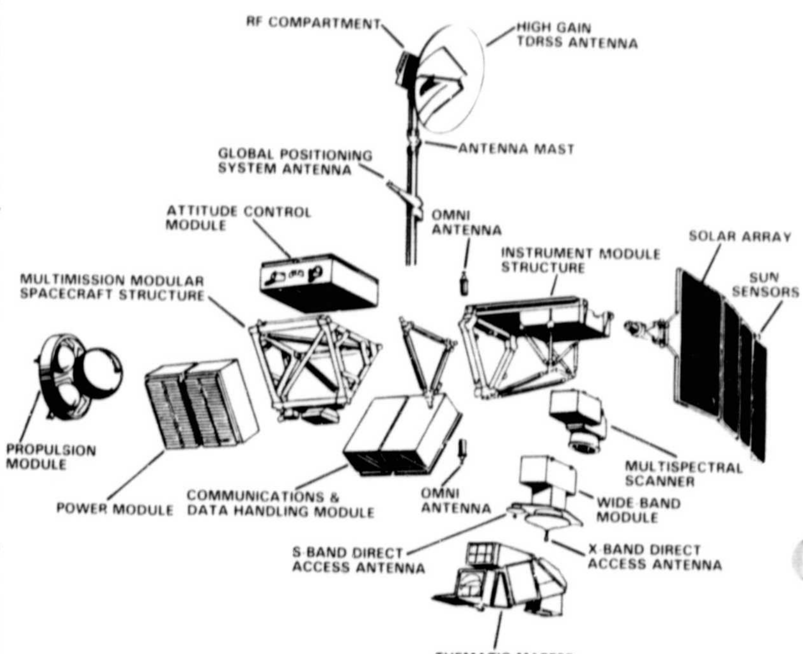
In addition to the roles of the TDRS and DOMSAT systems, Global Positioning System (GPS) navigation satellites are expected to provide Landsat 4 with highly accurate position and velocity data. These data will be used both on board Landsat 4 and on the ground, where downlinked data could be used for geometric correction of TM and MSS imagery. Only 5 of the 18 GPS satellites that are planned, however, will be in orbit in the early 1980's.

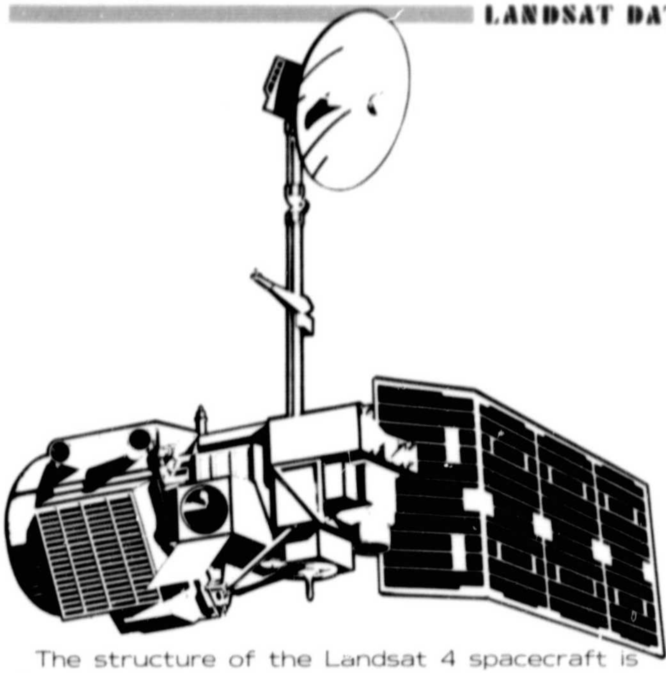
A diagram depicting all the satellites with which Landsat 4 will interact is provided on page 3.

The Landsat 4 spacecraft is also able to communicate with, and send data directly to, in-range ground receiving stations worldwide. For this purpose, X-band frequencies will be used for handling the TM and MSS data streams. Those stations not equipped to receive X-band transmissions will be able to obtain only MSS data in real-time, using an S-band frequency as have previous Landsats.

Delays in the deployment of the TDRS system are expected to significantly limit the amount of TM data that can be acquired by this means during the early phases of the Landsat 4 mission. A transportable ground station located at GSFC has therefore been provided to allow real-time TM data acquisition over the eastern United States, to approximately 100° W. longitude. TM data acquisition capabilities for the remainder of the United States will be provided following the deployment of the first TDRS vehicle (anticipated in early 1983). Landsat 4 MSS data will be acquired through the existing U.S. ground station network and selected non-U.S. stations until the TDRS system is fully operational.

From Goddard, radiometrically corrected MSS data in digital form will be relayed, again via DOMSAT, to the EROS Data Center (EDC). There, the data will be processed into master reproducible 241-mm (9-inch) film negatives, and stored in the form of high-density digital tapes (HDT's). No satellite transmissions of TM data between Goddard and EDC are planned. TM products will be in the form of 241-mm film and computer-compatible tapes (CCT's) produced at GSFC and will be shipped by air freight to the EDC distribution facility.





The structure of the Landsat 4 spacecraft is characterized by its large deployed mast which supports the TDRS antenna and by its single-wing solar array. The long dimension of the spacecraft body (the roll axis) lies in the plane of the orbit, the yaw axis is oriented to the local vertical (parallel to the antenna mast), and the pitch axis is normal to the orbit plane and parallel to the axis of rotation of the solar array.

The principal sensing instruments, the TM and the MSS, are located at the forward end of the instrument module. Each sensing instrument uses a moving mirror assembly to scan in the crosstrack direction (perpendicular to the spacecraft ground track) and depends upon the relative motion of the spacecraft to achieve the along-track scan.

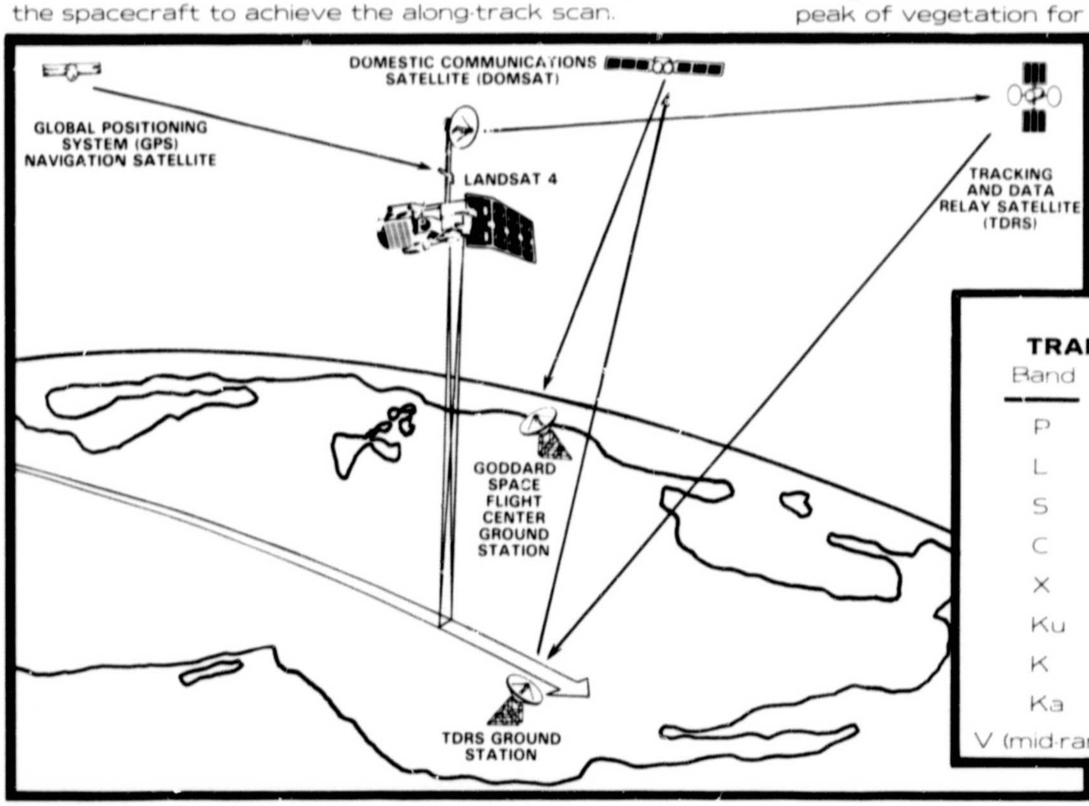
SENSORS

In terms of basic design, there are at least two fundamental differences between the MSS and TM. First, the TM scans and obtains data in both directions. The bidirectional approach was employed to reduce the scan rate and provide the dwell time needed to produce improved radiometric accuracy. Second, the TM detector arrays are located within the primary focal plane of the instrument, allowing incoming light to be reflected directly onto the detectors without transmission through fiber optics, as with the MSS. This configuration minimizes any loss in the intensity of incoming radiation. However, it requires that the detector arrays for various spectral bandwidths be spaced apart in the focal plane by the equivalent of several raster lines, meaning that the same point on the ground is not simultaneously scanned in all seven bands. Accurate TM band-to-band registration will thus depend on precise time registration and scan mirror profile linearity and repeatability.

Thematic Mapper

The TM operates in seven spectral bands. The selection of bands for this sensor was the subject of considerable study and debate. The band designations, spectral ranges, and principal applications are as follows:

- Band 1 (0.45-0.52 μm)
  Designed for water body penetration, making it useful for coastal water mapping. Also useful for differentiation of soil from vegetation, and deciduous from coniferous flora.
- Band 2 (0.52-0.60 μm)
  Designed to measure visible green reflectance peak of vegetation for vigor assessment.



SATELLITE TRANSMISSION BANDS

Band	Frequency (GHz)
P	0.3 - 1.0
L	1.0 - 2.0
S	2.0 - 4.0
C	4.0 - 8.0
X	8.0 - 12.5
Ku	12.5 - 18.0
K	18.0 - 26.5
Ka	26.5 - 40.0
V (mid-range)	50

- Band 3 (0.63-0.69 μm)
  A chlorophyll absorption band important for vegetation discrimination.
- Band 4 (0.76-0.90 μm)
  Useful for determining biomass content and for delineation of water bodies
- Band 5 (1.55-1.75 μm)
  Indicative of vegetation moisture content and soil moisture. Also useful for differentiation of snow from clouds.
- Band 6 (10.40-12.50 μm)
  A thermal infrared band of use in vegetation stress analysis, soil moisture discrimination, and thermal mapping.
- Band 7 (2.08-2.35 μm)
  A band selected for its potential for discriminating rock types and for hydrothermal mapping.

These spectral bands were chosen primarily for vegetation monitoring. The one exception is band 7, which was added primarily for geological applications.

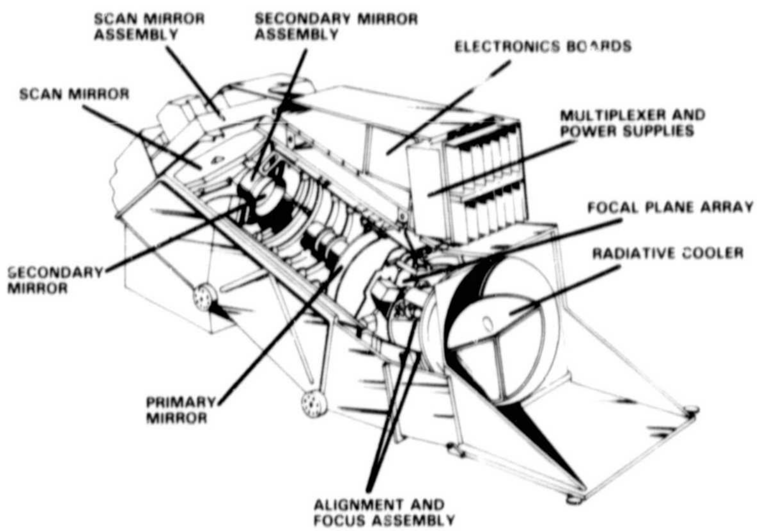
An important design goal was the achievement of better radiometric sensitivity in all bands. The radiometric sensitivity of the TM (table 1) is much improved over that of the MSS, even though the TM spectral bandwidths are narrower and the ground sample size (pixel size) is smaller. In conjunction with this improvement, the number of quantization levels has been increased from 64 to 256.

Improved spatial resolution (over that of the MSS) is another attribute of the TM. A pixel size of 30 m (ground resolution) in all but band 6 will allow classification of areas as small as 2½ to 4 ha (6 to 10 acres). Band 6, a thermal band, will achieve a pixel size of 120 m on the ground.

These performance levels were determined by such factors as: (1) the detector instantaneous field of view (IFOV), which is a function of detector size and focal length of the telescope; (2) the optics of the telescope and the scan mirror, which were designed to minimize diffraction and blur; and (3) the electronic frequency response of the system, which was dictated by the dwell time afforded by other components of the system. Summaries of anticipated TM performance parameters are given in tables 2 and 3.

As shown in the accompanying cutaway diagram, the TM is mounted in the spacecraft in a horizontal position with the sun shade pointing toward Earth. Directly above the sun shade aperture is a scan mirror surrounded by its drive mechanisms, control electronics, and scan monitor hardware. The primary mirror is mounted about halfway down the length of the telescope, preceded by optical baffling and the secondary mirror. Directly behind the primary mirror are the scan line corrector, internal calibrator, and the visible detector focal plane with its mounting hardware and alignment mechanisms. The radiative cooler (containing the cooled focal plane assembly), relay optics, and infrared detector arrays are located on the instrument's aft end. The electronics package is contained in a wedge-shaped box above the telescope and contains the multiplexer, power supplies, signal amplifiers, and filters for all channels.

The detector assemblies for spectral bands 1-4 are located at the primary focal plane and employ 16 detectors for each band. The detector assemblies at the cooled focal plane consist of two



Thematic Mapper

TABLE 1
Thematic Mapper Radiometric Sensitivity

Effective Aperture: 1063 cm²
Effective Quantizer Bits: 7.75

Band	Optical Transmission	Responsivity (A/W)	Fixed Noise (pA)	Signal-to-Noise Ratio (S/N): Minimum Scene Radiance, Specified	Minimum Scene Radiance, Actual*	Maximum Scene Radiance, Specified	Maximum Scene Radiance, Actual*
1	0.77	0.33	2.3	32	52	85	143
2	0.77	0.40	2.3	35	60	170	279
3	0.90	0.45	2.1	26	48	143	248
4	0.76	0.56	2.2	32	35	240	342
5	0.69	1.2	4.9	13	40	75	194
7	0.65	1.6	4.8	5	21	45	164
6	0.53	15 kV/W		**NETD 0.5K	0.13 K		

*"Actual" ratios are based on initial calculations only and may be subject to refinement as reduction of observed test data continues

**NETD = Noise-equivalent temperature difference

high-resolution, near-infrared bands (5 and 7) with 16 detectors each, and one thermal band (band 6) with four detectors. Thus, during each scan mirror sweep, 16 scan lines of data are generated for each of bands 1-5 and 7, and four are generated for band 6.

A scan angle monitor on the scan mirror passes signals to the timing mechanism in the multiplexer to indicate the beginning, midscan, and end of the period in the scan mirror's travel when data are taken in the forward scan direction. Equivalent signals are provided for the beginning, midscan, and end of the reverse scan. A "line stop" signal at the end of each scan (both forward and reverse) indicates the end of the formatting period and is buffered and retransmitted to the scan line corrector to initiate motions which correct for overlap.

The scan line corrector, located in front of the prime focal plane, rotates the TM line-of-sight backward along the ground track to generate scan lines which are straight and perpendicular to the ground track. During each turnaround period of the scan mirror, the internal calibrator stimulates the individual channel voltages for all seven spectral bands, providing for routine monitoring of detector condition for use in ground processing of the image.

The TM collects radiometric data in the seven spectral bands by utilizing the detector assemblies of the primary focal plane array and the cold focal plane array. As the scan mirror sweeps the TM line-of-sight back and forth seven times per second in a direction normal to the ground track, it forms a raster of 16 lines in bands 1-5 and 7, and 4 lines in band 6, for each sweep direction. Data are collected during both the forward (west-to-east)

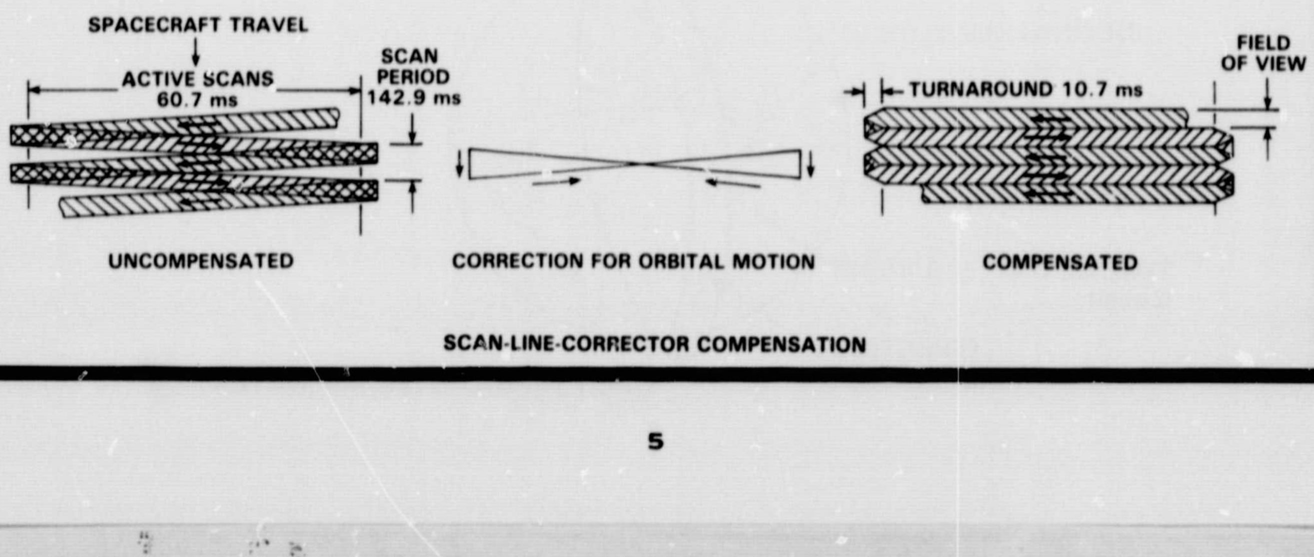
TABLE 2
Significant Thematic Mapper Parameters

Orbit:	Sun-Synchronous 705.3-km Altitude 98.9-min Period 98.2° Inclination 16-day Repeat Cycle
Scan:	185-km Swath 7.0-Hz Rate 85-percent Efficiency
Optics:	40.6-cm Aperture f/6 at Prime Focus 42.5-μrad IFOV, Bands 1-4 f/3 at Relay Focus 43.8-μrad IFOV, Bands 5,7 170-μrad IFOV, Band 6
Signal:	52 kHz, 3 dB, Bands 1-5, 7 13 kHz, 3 dB, Band 6 1 Sample/IFOV 8 Bits/Sample 84.9-Mbps Multiplexed Output

TABLE 3
Major Performance Requirements of the Thematic Mapper

Square-Wave Response: (Bands 1-5, 7	0.35 for 30 meter bars
Band-to-Band Registration:	<6 m
Scan Profile Repeatability:	<6 m
Along-Track Overlap/Underlap:	<6 m
Swath Width:	185 km
Radiometric Resolution:	
(Bands 1-5, 7)	0.5-2.4 percent NEϱ*
(Band 6)	0.5 K NETD**
Absolute Radiometric Accuracy:	10 percent
Band-to-Band Radiometric Precision:	2 percent
Channel-to-Channel Radiometric Precision:	$\leq \frac{\text{rms noise}}{4}$
Spectral Coverage:	0.45-12.5 μm
Signal Quantization Levels:	256
Data Rate:	84.9 Mbps
Weight:	243 kg
Power:	332 watts
Envelope:	0.66 m by 1.1 m by 2.0 m

*NEϱ = Noise-equivalent reflectance.
**NETD = Noise-equivalent temperature difference.



SCAN-LINE-CORRECTOR COMPENSATION

and reverse (east-to-west) scans. The Ritchey-Chretein telescope images the scanned scene energy onto the prime focal plane as the scan line corrector is operating to provide forward and reverse scan swaths adjacent to each other. At the prime focal plane, each band (bands 1-4) employs a 16-element detector array to translate the sensed scene energy into low-level electrical signals which are amplified, converted to 8-bit digital words, and then multiplexed into an 84.9-megabit-per-second (Mbps) data stream which is transmitted to the ground. A two-mirror, all-reflective relay reimages the incoming energy from bands 5, 6, and 7 onto the cooled focal plane located in the radiative cooler. At the cooled focal plane also, energy is converted into low-level electrical signals, amplified, and translated into 8-bit digital words which are multiplexed into an 84.9-Mbps data stream for transmission to the ground.

Multispectral Scanner

The MSS on Landsat 4 is similar to the MSS instruments that were flown on Landsats 1, 2, and 3. However, in order to provide MSS data compatible with that acquired from the higher orbits flown by Landsats 1, 2, and 3 (about 920 km), the optics of the Landsat 4 MSS system have been adjusted so that the pixel size still approximates an 80-m ground area. In addition, a new numbering system is being used to designate the four spectral bands of the Landsat 4 MSS. What are known as bands 4, 5, 6, and 7 on the previous MSS sensors, are now known, respectively, as Landsat 4 MSS bands 1, 2, 3, and 4. This is a change in designation only. The spectral coverage of the instrument will remain the same.

ORBIT AND COVERAGE

Landsat 4 is expected to assume a repetitive, circular, Sun-synchronous, near-polar orbit at a nominal altitude of 705 km (431 mi) over the equator. The satellite will cross the equator at approximately 9:45 a.m. on each pass. Each orbit will take nearly 99 minutes, and the spacecraft will complete just over 14½ orbits per day, covering the entire Earth (poles excepted) every 16 days. Major orbital characteristics are shown in the diagram below.

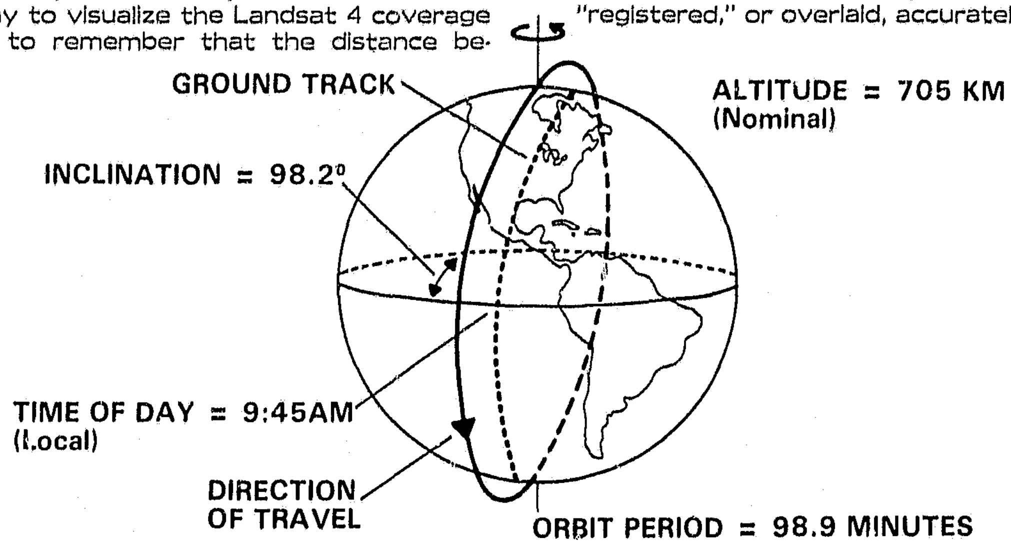
This compares to the similar but higher orbits of Landsats 1, 2, and 3, which had altitudes of 920 km (570 mi), completed each orbit in 103 minutes (14 times a day), and covered the Earth every 18 days.

The lower orbit of Landsat 4—necessary for the 30-m ground resolution of thematic mapper data—results in an Earth coverage cycle significantly different from that of the earlier Landsats. For Landsat 4, the adjacent swath to the west of a previous swath is covered 7 days later. This is in contrast to Landsats 1, 2, and 3, where the adjacent swath to the west was established just 1 day later. A convenient way to visualize the Landsat 4 coverage pattern is to remember that the distance between any two consecutive orbits (moving westward) is 2,752 km at the equator. The rest of the area between these ground tracks fills in over a 16-day period, whereupon the coverage pattern starts repeating itself.

At the equator, adjacent swaths overlap at the edges by 7.6 percent. Moving from the equator toward either pole, this "sidelap" increases because of the fixed swath width of 185 km.

The Landsat 4 16-day ground coverge cycle is accomplished in 233 orbits, making it incompatible with the 251-orbit Worldwide Reference System (WRS) path/row indexing scheme that is used with data from previous Landsats. The WRS path/row system for Landsat 4 is made up of 233 paths numbered from 001 to 233, east to west, with path 001 crossing the equator at 64.95° W. longitude. The same number of rows, however, are still used. The rows are positioned so that row 60 coincides with the equator at the orbit's descending node, there being 248 rows in all.

Successive orbits and framing operations will be carefully controlled to ensure minimal variation to either side from the intended ground track and precise framing from top to bottom so that successive images of a specific scene can be "registered," or overlaid, accurately.



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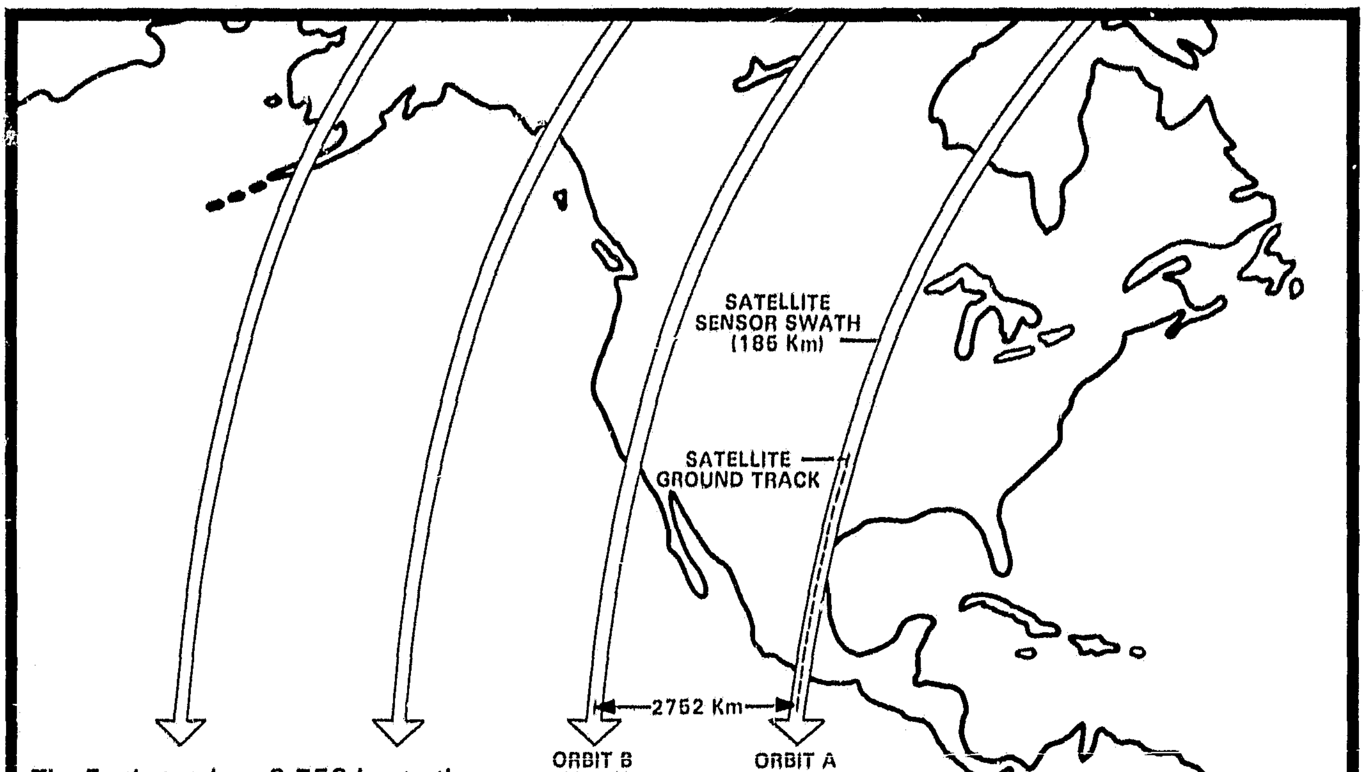
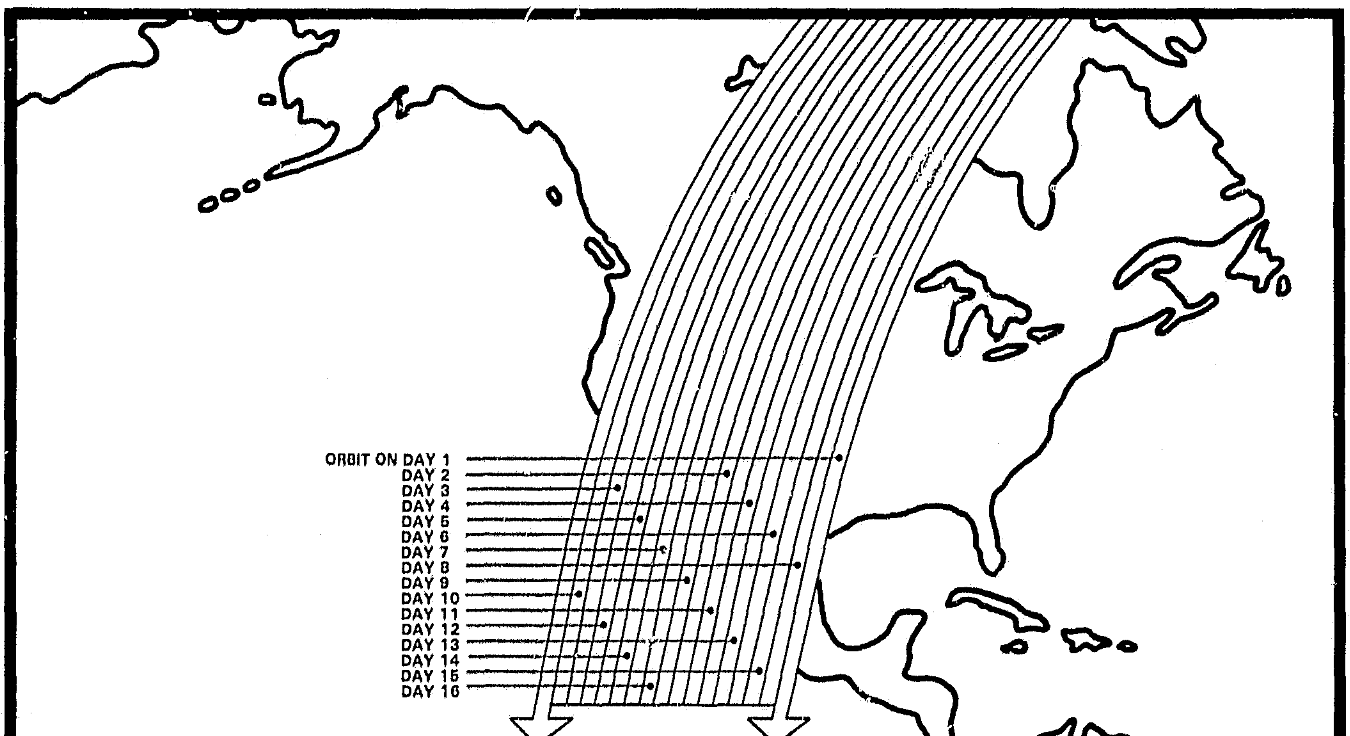


The Earth revolves 2,752 km to the east (at the equator) between passes.



Adjacent swaths (moving westward) are imaged 7 days apart.

GROUND SEGMENT

The Landsat 4 ground segment activity can be divided into two parts, one representing the facilities and preprocessing performed at Goddard and the other representing the final processing and distribution of data at EDC. A chart showing significant milestones for the ground segment over the next few years is provided below.

Goddard Space Flight Center

The Goddard portion of the ground segment consists of a Control and Simulation Facility, a Mission Management Facility, an Image Generation Facility, a Landsat Assessment System, and the Transportable Ground Station. The Image Generation Facility (IGF) is the most important of these, from the user's point of view, for here is where the raw instrument data from the satellite are processed toward final products for distribution.

The IGF receives and processes raw instrument data to produce film and digital Landsat data products from both the MSS and TM sensor systems. Importantly, there are two distinct image processing subsystems to provide for complete separability of TM and MSS processing. By doing this, the flow of MSS data to the user community can be maintained without being affected by the data processing research and development that will be going on (for at least the first year) with TM data. The computer systems used to process both types of data also incorporate a high degree of redundancy to maximize processing reliability.

The MSS element of the IGF was scheduled to become operational 14 days after launch. The TM element will function initially in a research and development mode and will subsequently evolve into an operational system after the TM sensor and its performance are characterized.

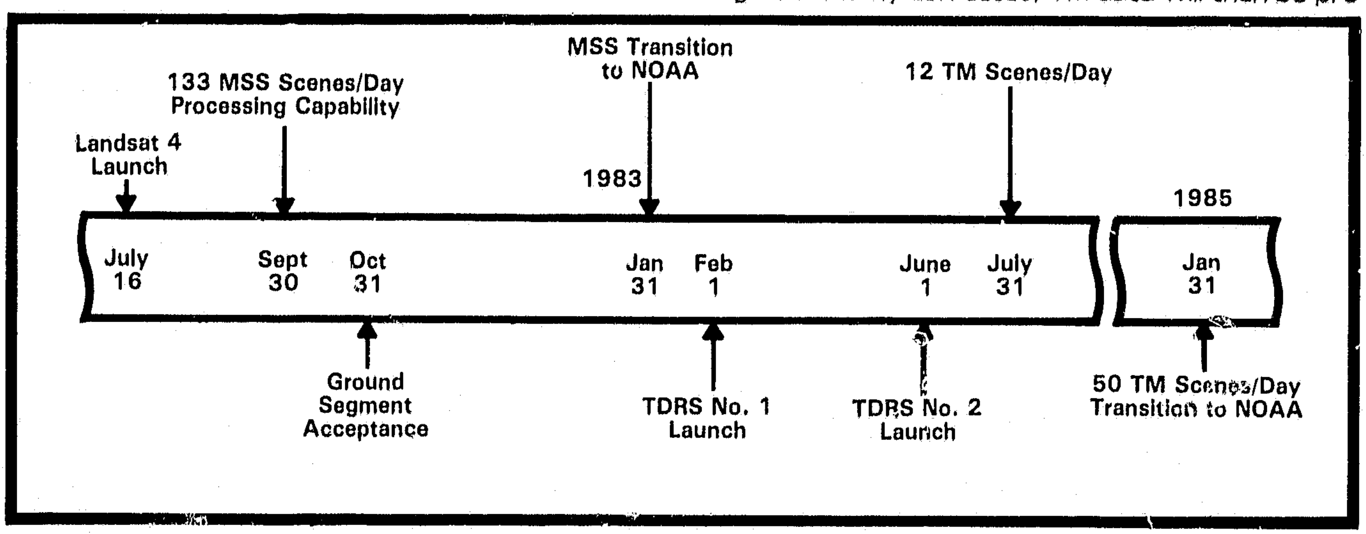
Within the IGF, MSS data are to be produced at a rate of about 133 scenes per day during the first months of operation, and it will be possible to increase this rate to 200 scenes per day if demand warrants. These preprocessed data will be in the form of radiometrically corrected, high-density digital tapes (HDT-A's). The HDT-A data will be transmitted via DOMSAT to the EROS Data Center, at Sioux Falls, S. Dak., where geometric corrections will be applied and various user products in both digital and film format will be produced.

The acquisition, processing, and distribution of TM data will be more complex, primarily due to the increased data output of the sensor and its associated ground systems. The need to perform engineering assessments and validations, and the fact that it is not possible to implement a full TM processing capability prior to launch, are also factors. Operational output of TM data products is not expected until January 1985.

In the first year after launch, TM data will be acquired primarily over the United States at a rate of 30 scenes per day and will be stored at GSFC for processing in the event of early failure of the TM. From these 30 scenes, TM data will be processed at GSFC at a rate of approximately 1 scene per day. These data will be produced in the form of: (1) 241-mm black-and-white paper prints and film transparencies for each of the seven bands of the TM; (2) false-color composites made from bands 2, 3, and 4; and (3) computer-compatible tapes.

These data will be used to evaluate the performance of the TM and will be a close approximation, in terms of format, to the standard products to be eventually produced by the TM Image Processing System (TIPS) within the IGF. The TIPS will begin operation in July 1983. Sample data acquired in the first year, before the TIPS is operational, will be distributed to EDC to permit the availability of at least a limited amount of TM scene data. These products will be available no earlier than approximately 90 days after launch, and distribution will be made only with NASA's concurrence. The price structure for sales of these early data will be announced by NOAA before August 1, 1982.

When the TIPS begins operation, data will be processed at a rate of approximately 12 scenes per day. This will continue until January 1985 when the TM ground processing systems at Goddard and all associated Landsat 4 systems will become the responsibility of NOAA to manage in an operational mode. Fully processed (radiometrically and geometrically corrected) TM data will then be pro-



duced at a rate of about 50 scenes per day.

A paramount concern in the design and development of the Landsat 4 ground segment has been the necessity for generating quality data products in a timely manner. A 48-hour turnaround in the IGF is a design objective, and a high level of "backup" capability using proven data processing components has been incorporated wherever possible. New image generation procedures also allow ample margin for reprocessing a substantial part of the production requirement each day, if necessary, to eliminate errors caught in quality checking.

The radiometric correction procedures have been a subject of key interest. It is expected that, for the MSS, a calibration-wedge approach will be used to assess absolute and band-to-band fidelity during Landsat 4 operation, and scene content histogramming will be used to monitor detector-to-detector gain and bias and to achieve the ±1 quantum level specification. On the TM, a series of three lamps will be operating at different intensities to provide eight levels of calibration intensity over the range of response for the instrument.

The geometric correction specifications for MSS and TM data are quite stringent, especially for the TM. The improved attitude control capability of Landsat 4 may expedite the processing of MSS data in particular. However, the installation of the angular displacement sensor on the TM reflects the concern for the so-called "jitter" effects that can result from the interaction of the scan vibrations produced by the MSS and TM mirrors and the drive mechanisms of the TDRS antenna and the solar array. The information provided by the angular displacement sensor will be used to account for high-frequency vibrations that may affect the band-to-band registration and other geometric specifications already noted.

Corrections by the ground processing system must also be made to account for off-nadir ("bow-tie") effects and scan gap or overlaps in TM data

TABLE 4
Landsat D Ground Segment Performance Requirements

Turnaround:	48 hours after receipt of raw sensor data at GSFC to generation of archival products (worst-case averaged over 10 days).
Radiometric error correction (relative interdetector):	±1 quantum level over full range.
Geometric error correction (nominal conditions with ground control points):	0.5 sensor pixel (90 percent of the time with sufficient ground control points that can be correlated).
Temporal registration error:	0.3 sensor pixel (90 percent of the time with sufficient control points that can be correlated).
Map projections supported:	Space Oblique Mercator.
	Universal Transverse Mercator Polar Stereographic.
Resampling algorithms supported:	Cubic convolution or nearest neighbor.

that may occur because of normal variations in orbital altitude.

Algorithms to account for the effects mentioned above, and others, are being developed and will be supplemented to attain the geodetic and temporal registration requirements specified for Landsat 4 data. The selection and use of ground control points will be an integral part of the overall process and will be an especially challenging procedure where the accuracies needed for the TM data become involved. Table 4 summarizes a few of the major performance requirements of the Landsat 4 ground segment.

EROS Data Center

The EDC portion of the Landsat 4 ground segment will handle any additional processing of the data not done by Goddard. This includes final formatting of the data into user products, the application of optional corrections and enhancements as specified by users, and the operation of all inquiry, order, accounting, and data base management functions as necessary to maintain a central user archive and data distribution center. One of EDC's new responsibilities in the Landsat 4 period is to receive and process user requests for sensor acquisitions. Some preliminary information on this "special-acquisition" system can be found in the article following this one.

As mentioned earlier, radiometrically corrected MSS scene data in digital form (HDT-A's) will be transmitted via the DOMSAT link from Goddard to EDC as they are now for Landsat 3. Upon receipt, these data will be recorded by 14-track high-density digital tape recorders equipped with error-detection-and-correction circuitry.

The data will then be processed by a computer-based production system called the EROS Digital Image Processing System (EDIPS). EDIPS is a custom-built, real-time data processing system that can read digital image data from HDT's, apply geometric corrections, optionally perform certain kinds of image enhancement processing, and, finally, record the processed data on high-resolution photographic film or standard-density computer-compatible tapes (CCT's). Both types of products, film and tape, are archived at EDC in a central data base from which users can order reproductions.

In the standard processing mode, MSS sensor data are geometrically corrected to remove distortions caused by the sensor scanning mechanism, spacecraft attitude and orbital position variations, aspect ratio, Earth rotation, Earth curvature, and other systematic effects. These corrections are applied using ancillary data provided on the HDT received from Goddard. They permit the image to be conformed to a simple oblique Mercator coordinate system. In the case of Landsat 4, that system will be the Space Oblique Mercator (SOM) projection; the pixel resampling technique used to create this projection will be the cubic convolution technique.

In addition to the geometric corrections, a histogram of pixel brightness values is generated for each image, and an image enhancement algorithm designed to compensate for at-

mospheric scatter (haze) is applied.

Several other enhancements, map projections, and corrections of various kinds are available to the user should a nonstandard product be desired. Usually, orders for either tape or photographic products are completed and shipped within 10 working days after receipt.

When placing an order for a CCT, the user must specify the data type (radiometrically corrected only or both radiometrically and geometrically corrected), the tape bit-density (800-, 1600-, or 6250-bpi), and the scan-line sequence (band-sequential or band-interleaved-by-line).

Photographic products are generated from a master film negative printed by the EDIPS laser beam recorder. Black-and-white images, on either film or paper, and false-color composite images are available at a variety of enlargement sizes. All reproduction prints are individually analyzed to select an exposure that will reproduce the majority of image detail within the linear (usable) portion of the tone reproduction curve.

As noted previously, limited amounts of TM data may be made available to the user community beginning approximately 90 days after launch of Landsat D. These data will be in the form of 241-mm (9-in.) photographic prints as well as digital products. Studies are in progress at this time to determine the exact form that standard TM user products will eventually take.

It is currently planned that high-resolution film of fully corrected TM scenes will be shipped by common carrier to EDC for placement in the central archive and generation of reproductions for sale. Digital magnetic tapes in CCT format are also planned, again to be provided by Goddard and distributed to users by EDC.

Inquiries concerning Landsat 4 data products of all types are invited by EDC. Information on format, processing life, availability, price, and other matters of concern to the potential user may be obtained by contacting:

User Services Section
U.S. Geological Survey
EROS Data Center
Sioux Falls, SD 57298
telephone: (605) 594-6151.

MSS ACQUISITION REQUESTS

When the Landsat 4 MSS becomes operational, acquisitions by the MSS sensor will be scheduled in large part in response to user requests. These requests will be received by EDC, who will consolidate all requirements for specific MSS scenes, handle the associated billing and accounting functions, and forward the acquisition requirements to Goddard for scheduling.

Implementation of this system will represent a significant change in acquisition policy in that it will give first priority to those users who have specified scene requirements and are willing to bear the cost of acquiring these scenes. Any remaining MSS acquisition capacity will be used as much as possible to collect additional data which, although not specifically ordered in advance, would constitute a Basic Data Set of scenes deemed likely to be used at some future time.

The User Services Section at EDC will process the customer's MSS acquisition requests and provide periodic status reports to each customer. Customers will be expected to consider and then furnish the following information when requesting a sensor acquisition:

1. Geographic area of interest, by latitude and longitude.
2. Date(s) of coverage desired
3. Maximum acceptable cloud cover.
4. Data compression mode (compressed or decompressed).
5. Sensor gain (high or low).
6. Type of final products desired after successful acquisition.

Payment sufficient to cover all costs must accompany each request. Refer to Issue No. 21 of this newsletter (dated Jan. 1982) for a price list.

EDC's User Services Section will be happy to assist prospective requesters. The telephone number is (605) 594-6151. Written queries may be addressed to:

User Services Section
U.S. Geological Survey
EROS Data Center
Sioux Falls, SD 57198
telephone: (605) 594-6151

THE MSS BASIC DATA SET

Landsat 4 MSS data acquisitions will be partly determined by the requirements of what is known as the MSS Basic Data Set.

The scenes acquired for this Basic Data Set will represent the more routine data collection activities of the satellite. To determine the criteria that should be used to select MSS Basic Data Set scene candidates, NOAA held a series of public meetings this spring to solicit opinions from the user community. NOAA will publish a description of the MSS Basic Data Set late in 1982 in order to inform users of which MSS scenes they can expect to be collected under this program. Although Basic Data Set collections are not guaranteed, NOAA pledges a "best effort" to complete them. The archive of Landsat products thus built will be available for purchase without an initial special-acquisition fee being attached. The coverage provided will also be relatively systematic and repetitive, as long as higher-priority special acquisitions do not preempt system capabilities.

Regardless of how obtained, routine collection or customer-requested, all Landsat MSS data products will be entered into the public domain.

Inquiries regarding MSS Basic Data Set acquisition policy may be addressed to:

National Oceanic and Atmospheric
Administration (NOAA)
National Earth Satellite Services
User Affairs Division, Sx32
Federal Building 4, Mail Stop D
Washington, D.C. 20233.

PRINCIPAL INVESTIGATORS SELECTED

To help characterize the performance of the Landsat 4 system and the products obtained from it, an investigator team representing the user community was recently selected to study and document certain areas of special interest. The selections were made based on response to the Landsat D Image Data Quality Analysis (LIDQA) Application Notice issued October 23, 1981 (see issue No. 20 of the NOTES). The 50 proposals that were submitted were individually evaluated by a panel of peers from universities, private industry, and Government agencies. Of these, 24 were provisionally selected for participation in the program.

A list of the investigators and the titles of their proposals are provided below. The LIDQA program will extend, in general, from the time of Landsat 4's launch through January 1985.

PRINCIPLE INVESTIGATOR	AFFILIATION	PROPOSAL TITLE
James Anderson	NASA/Earth Resources Laboratory	Landsat scene-to-scene registration assessment.
Paul Anuta	Purdue University/ Laboratory for Applications of Remote Sensing (LARS)	Research on Landsat D image data quality analysis.
Lee Bender	U.S. Geological Survey	Evaluation of radiometric and geometric characteristics of Landsat D imaging systems.
Ralph Bernstein	IBM Corporation	Landsat D sensor and system data analysis and image science.
Robert Colwell	University of California, Berkeley	Analysis of the quality of image data acquired by the Landsat MSS.
Jeffery Dozier	University of California, Santa Barbara	Landsat D investigations in land cover and snow hydrology.
Jon Erickson	NASA/Johnson Space Center	TM and TM image processing system performance in agricultural applications technique development.
John Everett	Earth Satellite Corporation	Evaluation of Landsat D TM performance as applied to hydrocarbon exploration.
Charlotte Gurney	Systems and Applied Sciences Corporation	The use of linear feature detection to investigate TM data performance and processing.
Charles Hill	NASA/Earth Resources Laboratory	Evaluation of Landsat D TM and MSS resource information requirements.
Warren Hovis	NOAA/National Earth Satellite Service	Development of atmospheric correction procedures and post-launch calibration validation for the Landsat D TM.
Michael Jackson	Natural Environment Research Council, United Kingdom	Spatial analysis of TM products.
Hugh Kieffer	U.S. Geological Survey	Geometric and radiometric characterization of Landsat D TM and MSS data.
Donald Lauer	U.S. Geological Survey	Investigations of TM and MSS data applications.

Robert MacDonald	NASA/Johnson Space Center	Landsat D image data analsyis.
William Malila	Environmental Research Institute of Michigan	Spectral/Radiometric characteristics of the TM.
William Malila	Environmental Research Institute of Michigan	Radiometric consistency of Landsat D MSS.
John Price	U.S. Department of Agriculture/Agricultural Research Service	Information content of data from the Landsat D TM and MSS.
John Schott	Rochester Institute of Technology	Evaluation of the radiometric integrity of Landsat D band 7 data.
Philip Slater	University of Arizona	Spectroradiometric calibration of TM and MSS systems.
W.M. Strome	Canada Centre for Remote Sensing, Canada	Evaluation of Landsat D MSS and TM data.
Roy Welch	University of Georgia	Comparative assessment of Landsat D MSS and TM data quality for mapping applications in the Southeast
Robert Wringley	NASA/Ames Research Center	An investigation of several aspects of Landsat D data quality for the LIDQA program.
Albert Zobrist	NASA/Jet Propulsion Laboratory	Evaluation of Landsat D TM and MSS ground segment geometry performance without ground control.

SIMULATED TM DATA BEING STUDIED AT EDC

In anticipation of the availability of Landsat 4 TM data, numerous Government, academic, and private research organizations have been conducting studies of aircraft-acquired data from scanners which provided spectral and spatial resolution characteristics similar to those of the TM on Landsat 4. Most of these studies have been directed toward evaluating the additional benefits, in terms of specific problem-oriented applications, which can be expected from TM data. Notable success, for example, has been demonstrated in the area of improved lithologic discrimination, particularly in the identification of zones of hydrothermal alteration in sparsely vegetated areas. Such success is primarily a result of data acquired in the 2.10-to 2.34-μm region of the electromagnetic spectrum (which corresponds to TM band 7). Hydrous minerals, which are a dominant constituent of most hydrothermal alteration zones, exhibit strong absorption bands in this region and result in unique spectral signatures on images produced from data which include this portion of the spectrum.

Studies are currently being conducted at EDC to evaluate the capabilities of TM data in discriminating lithologic variations in sedimentary rocks and in detecting surficial effects related to subsurface hydrocarbon occurrences. TM Simulator (TMS) data have been acquired by NASA over selected areas in the Uinta and Piceance sedimentary basins of northeastern Utah and northwestern Colorado, and they are being studied along with high-spectral-resolution (up to 950 bands between 0.34 and 2.58 μm) ground and airborne spectroradiometric data collected from the same areas. The ground and airborne data are being used in the calibration of the TMS data as well as in designing optical digital image processing techniques to be applied to the TMS data. Although the work is not complete, initial results show that TMS data acquired over the Split Mountain anticline (east of Vernal, Utah) can be digitally processed to produce images which permit significantly better separation of sedimentary units than can be accomplished with images produced from Landsat MSS data.

NEW CCT FORMAT TO BE IMPLEMENTED

Concurrent with the launch of Landsat 4, EDC will begin offering computer-compatible tapes (CCT's) of Landsat MSS data in a new format. This format will conform to the guidelines recommended by the Tape Standards Committee of the Landsat Ground Station Operators Working Group, as announced in Issue No. 21 of this newsletter last January.

The CCT format now being used will be retained for approximately 1 year after launch, meaning that two formats will be available for a period of time. The format now being used is referred to as the Landsat MSS VERSION 0. The new format is referred to as the Landsat MSS VERSION 1. Both the VERSION 0 and the VERSION 1 formats will be available for any Landsat MSS data acquired after January 1, 1979, until VERSION 0 is discontinued. At that time, VERSION 1 will be the only CCT data format available. The old "CCT-X" format will still be used for any data acquired before Jan. 1, 1979.

Documentation of the new Landsat MSS VERSION 1 format and sample CCT's (at a reduced price) can be obtained from EDC. Interested users should contact:

User Services Section
U.S. Geological Survey
EROS Data Center
Sioux Falls, SD 57198
telephone: (605) 594-6151

SYMPOSIA

A symposium entitled **Advances in Instrumentation of Processing and Analysis of Photogrammetric and Remote Sensing Data** will take place August 30 to September 3, 1982, in Ottawa, Canada. It is sponsored by Commission II of the International Society of Photogrammetry and Remote Sensing. A call for papers has been issued. For further information, contact Z. Jaksic, President, Commission II (ISPRS), Division of Physics, National Research Council of Canada, Bldg. M-36, Montreal Road, Ottawa, Ontario K1A 0R6, Canada, telephone: (613) 993-2074.

A **National Conference on Energy Resource Management** will be held September 9-12, 1982, in Baltimore, Md. This conference is being jointly sponsored by the American Planning Association's Energy Planning Division and the Eastern Regional Remote Sensing Application Center (ERRSAC) of NASA's Goddard Space Flight Center. The objective is to bring together professionals in the field of energy resource management, energy facility sitings, energy resource extraction, remote sensing, geographic information systems, and related disciplines from the United States and other countries. Participants will focus on the use of remote sensing in these disciplines. Information about the conference can be obtained from Yale M. Schiffman, The MITRE Corporation, 1820 Dolley Madison Blvd., McLean, VA 22101, telephone: (703) 827-7243.

The **International Society for Photogrammetry and Remote Sensing** will host a symposium in Toulouse, France, September 13-17, 1982. The symposium will present the activities of the Society's Commission VII working group relevant to two main subjects: (1) the methodologies for joint operational use of photogrammetry and remotely sensed data and (2) the use of a new generation of operational satellites that should be available in the 1980's. An international exhibition will be held concurrently with the symposium. For further information, contact:

Groupement pour le developement
de la Teledection Aerospatiale
18, avenue Edouard-Belin
31055 Toulouse Cedex, FRANCE
Tel: (61)53.11.12

A symposium entitled **Resources Survey for Land Use Planning and Environmental Conservation** will be held October 20-22, 1982, at the Indian Photo-Interpretation Institute, under the auspices of the Indian Society of Photo-Interpretation and Remote Sensing, Dehra Dun. The symposium will be co-sponsored by many national departments and institutes. All correspondence related to the symposium may be addressed to Prof. D. P. Rao, Organizing Secretary (ISPI&RS), Indian Photo-Interpretation Institute, 4 Kalidas Rd., Dehra Dun-248001, U.P. (INDIA).

SHORT COURSE ON NATURAL RESOURCE SURVEYING

The Cranfield Institute of Technology, in Bedford, England, has announced plans to repeat a 5-day short course it held last January on the subject of "Remote Sensing for Natural Resource Surveying." The course was run by the Faculty of Agricultural Engineering, Food Production, and Rural Land Use, and it consisted of an intensive lecture program combined with case studies and practical exercises stressing remote sensing applications and computer-aided image analysis.

Those who are interested in attending such a short course in the near future are invited to contact Dr. J. C. Taylor, c/o The Short Course Secretary, National College of Agricultural Engineering, Silsoe, Bedford, MK45 4DT, United Kingdom.

PUBLICATIONS

The University of Rhode Island's Marine Advisory Service has announced a new reference manual entitled **A Guide to Environmental Satellite Data.** The document is designed particularly for scientists wishing to use satellite remote sensing as a tool for studying the coastal and ocean environment, but its use would not be restricted to this purpose. The 469-page volume is priced at $20. Inquiries should be made to the University of Rhode Island, Marine Advisory Service, Publications Unit, Naragansett Bay Campus, Naragansett, RI 02882.

SELF-INSTRUCTIONAL MODULES IN REMOTE SENSING

Purdue University has announced the release of six self-instructional, audiovisual modules dealing with remote sensing topics. Each module, or "mini-course," consists of 35-mm color slides, an audio tape, a printed study guide, and in many cases additional maps and photographs. The instructional level is appropriate for both professional training and university courses. Produced by the Laboratory for Applications of Remote Sensing (LARS) at Purdue, these new modules augment a collection of 19 units released previously as part of the LARS **Fundamentals of Remote Sensing** series. The newly released titles are as follows:

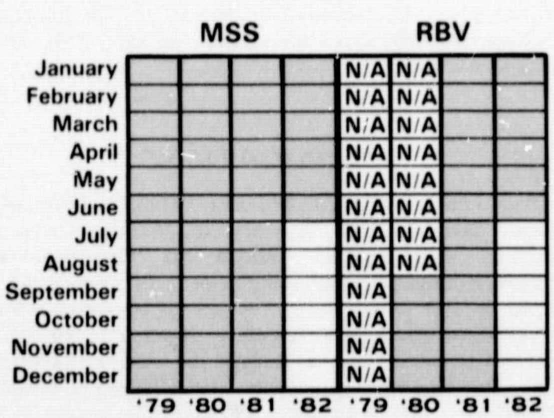
- "Principles of Photointerpretation"
- "Interpretation of Thermal Energy"
- "Mineral Exploration Using Satellite Data"
- "Selecting Landsat Imagery"
- "Photogeology"
- "Spectral Measurements for Field Research"

For further information about these and other remote sensing instructional materials available from Purdue, contact Gerald W. O'Brien, Director, Division of Independent Study, 116 Stewart Center, Purdue University, West Lafayette, IN 47907, telephone: (317) 494-7231.

STATUS OF GSFC DIGITAL PROCESSING

The backlog of Landsat digital processing at GSFC, which has been tracked in the chart below for the last several issues, has recently been eliminated. As shown by the shaded areas in the chart, all processable Landsat MSS and RBV data acquired through July 1, 1982, have been processed and sent to EDC.

LANDSAT DIGITAL PROCESSING STATUS AT GSFC
(RADIOMETRICALLY CORRECTED DATA ONLY)



NA = Prior to digital operations; no backlog incurred.
= Digital processing backlog closed out; all scenes at EDC

NOAA'S MANAGEMENT OF THE OPERATIONAL LANDSAT SYSTEM

[The following remarks were contributed by NOAA's National Earth Satellite Service]

NOAA's National Earth Satellite Service (NESS) has managed this nation's operational weather monitoring satellite programs since the beginning of this activity in the early 1960's. Through the years, this agency has maintained reliable operational polar-orbiting and geostationary satellite systems which provide, along with more obvious weather and ocean services:

- Information needed to track severe storms and hurricanes more closely.
- Measurements of the temperature and wind at various levels of the atmosphere for use in weather forecasting.
- Locations of ocean temperature fronts, significant in efficient maritime navigation as well as locating commercial quantities of fish.
- Estimates of the amount of rainfall in potential flash flood situations.

All such services must be provided under tight timelines, 24 hours a day, every day of the year, and NOAA/NESS has consistently met this challenge.

These NOAA operational characteristics, and its experience, organization, approach, and performance, influenced the decision to implement the operational Landsat program under NOAA management. In fact, experience was cited in the announcement that assigned Landsat to NOAA in 1979.

Duplicating this success in its Landsat activities is the NOAA goal. NOAA has a Landsat management team in place and preparations for taking over the operation, after the system is checked out, are well underway.

NOAA will be the single manager of the operational Landsat program, responsible for spacecraft scheduling, ground processing and production, and customer services. Single agency management will assure customers of a single point of contact for all Landsat services and will allow NOAA to fit the system's pieces—satellites, ground facilities, communications, and people—to the single purpose of supporting customers.

Customer service and efficient production are the cornerstones of the NOAA operation. When NOAA was assigned the Landsat operational system in November 1979, it began a program to inform and gain feedback from interested individuals and organizations. This contact continues today with a series of meetings scheduled throughout the country in May and June to solicit views from the user community concerning the makeup of the routine collection of data from Landsat. This routine collection program has been called the Basic Data Set (the subject of an article elsewhere in this issue).

Single-agency management of the Landsat operation will allow NOAA to achieve efficiency in production. NOAA plans to have all requests for Landsat data forwarded to EDC. There, these requests will be divided into retrospective and special acquisitions. Retrospective requests will be

filled directly from the archive; special acquisitions will be forwarded to the spacecraft command and scheduling activity at Goddard for spacecraft scheduling. Each order will be tracked from beginning to end in a special data base that will have the up-to-the-minute status of each order.

As the single manager of the total system, NOAA will be in a position to plan and control the production of Landsat products in the most efficient manner. This is all the more important today as the cost of the operation must be recovered through fees charged to users.

With the cooperation of the customer community and NOAA's two decades' experience in operational production, the Landsat program will deliver cost-effective solutions to the problem of Earth resources monitoring.

EDC COURSE ANNOUNCEMENT

The EROS Data Center will be offering a training course entitled **The Role of Remote Sensing in a Geographic Information System** from December 6-10, 1982. This specialized course will emphasize the contributions of remotely sensed and other kinds of spatial data (including terrain models) to geographic information systems, as well as the types of spatial analyses commonly used for natural resource applications. The course is designed for remote sensing analysts and resource specialists and assumes an understanding of the fundamentals of remote sensing. For more information, contact the Chief, Training and Assistance, Branch of Applications, U.S. Geological Survey, EROS Data Center, Sioux Falls, SD 57198.

REMOTE SENSING TRAINING

Aug. 2-5 — **Remote Sensing and Digital Image Processing** (San Francisco, Calif.) Contact: Dr. Ed Winter, Technical Research Associates, 350 N. Lantana, Suite 661, Camarillo, CA 93010, telephone: (805) 987-1972.

Sept. 13-17 — **Applying Remote Sensing Techniques to the Marine Environment** (Washington, D.C.) Contact: Continuing Engineering Education, George Washington University, Washington, D.C. 20052, telephone: (202) 676-6106.

Oct. 4-8 — **The Application and Processing of Landsat Data** (Murray, Ky.) Contact: Dr. Neil V. Weber, Director, Mid-America Remote Sensing Center, Murray State University, Murray, KY 42071, telephone: (502) 762-2148.

Oct. 18-22 — **Remote Sensing for Global Resource Applications** (Washington, D.C.) Contact: Continuing Engineering Education, George Washington Univeristy, Washington, D.C. 20052, telephone: (202) 676-6106.

Oct. 25-29 — **Digital Image Processing of Earth Observation Sensor Data** (Washington, D.C.) Contact: Continuing Engineering Education, George Washington University, Washington, D.C. 20052, telephone: (202) 676-6105.

EDC LANDSAT PRODUCTION STATISTICS

	Dec. '81		Jan. '82		Feb. '82		Mar. '82		Apr. '82		May '82		6-Month Total	
	MSS	RBV	MSS	RBV	MSS	RBV	MSS	RBV	MSS	RBV	MSS	RBV	MSS	RBV
Landsat scenes acquired (satellite acquisitions)*	1,464	411	1,191	406	839	260	1,263	465	2,504	626	2,158	544	9,419	2,712
Landsat MSS scenes/RBV subscenes received at EDC	2,464	2,735	1,500	3,650	1,147	3,362	945	3,222	1,847	1,744	1,562	1,711	9,465	16,424
Average time in days from EDC receipt to archive availability	22.8	14.0	31.1	9.6	9.7	15.4	4.3	5.9	9.7	6.9	8.0	8.6	–	–
Average delivery time in days from receipt of order at EDC to shipment:														
Standard photographic products	20		17		9		10		13		13		–	
Standard digital products	14		9		6		6		12		7		–	
Landsat photographic frames sold	8,258		7,117		8,078		5,860		9,076		7,385		45,774	
Landsat digital scenes sold	351		208		263		280		181		497		1,780	
TOTAL LANDSAT DOLLAR VOLUME	$221,788		$182,828		$224,076		$185,240		$213,641		$262,242		$1,289,815	

*Figures are revised periodically to reflect updated information received from NASA.

EDC TRAINING SCHEDULE

Aug. 30-Oct. 1 **International Remote Sensing Workshop: Applications in Vegetation Assessment and Land Use Planning** (Sioux Falls, S. Dak.) Open to non-U.S. scientists. Contact: Office of International Geology, U.S. Geological Survey, National Center, Mail Stop 917, Reston, VA 22092, telephone: (703) 860-6418.

Sept. 13-17 **Introduction to Remote Sensing for Land Cover Mapping** (Anchorage, Alaska) Open enrollment. Contact: Chief, USGS/EROS Field Office, 218 'E' Street, Anchorage, AK 99501. telephone: (907) 271-4065.

Oct. 25-29 **Terrain Analysis: Interpretation of Aerial Photographs and Images** (Sioux Falls, S. Dak.) Contact: Coordinator, Continuing Education Program, Harvard Graduate School of Design, Gund Hall, L-37, Harvard University, Cambridge, MA 02138, telephone: (617) 495-2578.

Nov. 1-5 **Hydrology Information Workshop** (Sioux Falls, S. Dak.) Open enrollment. Contact: Chief, Training and Assistance, Branch of Applications, U.S. Geological Survey, EROS Data Center, Sioux Falls, SD 57198, telephone: (605) 594-6114.

Nov. 15-19 **Advanced Geological Workshop** (Sioux Falls, S. Dak.) Open enrollment. Contact: Chief, Training and Assistance, Branch of Applications, U.S. Geological Survey, EROS Data Center, Sioux Falls, SD 57198, telephone: (605) 594-6114.

Dec. 6-10 **Role of Remote Sensing in a Geographic Information System** (Sioux Falls, S. Dak.) Open enrollment. Contact: Chief, Training and Assistance, Branch of Applications, U.S. Geological Survey, EROS Data Center, Sioux Falls, SD 57198, telephone: (605) 594-6114.

The Landsat Data Users NOTES is published bimonthly in order to present information of interest to the user community regarding Landsat products, systems, and related remote sensing developments. There is no subscription charge; individuals and organizations wishing to receive the NOTES should contact the User Services Section, U.S. Geological Survey, EROS Data Center, Sioux Falls, SD 57198, U.S.A., telephone: (605)594-6151.

Comments, corrections, and other inquiries should be directed to:

Editor, Landsat NOTES
U.S. Geological Survey
EROS Data Center
Sioux Falls, SD 57198

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APPENDIX B

LANDSAT GROUND RECEIVING STATION STATUS

The successful launch of Landsat 4 on July 16, 1982, and the takeover by NOAA of the operational running of the Landsat program necessitate a reevaluation of the status of world ground receiving stations.

Landsat Satellites 1, 2, and 3 communicated with ground receiving stations, both foreign and domestic, using S-band frequency transmissions. The Landsat 4 satellite will also be able to communicate with and send data directly to in-range ground receiving stations worldwide. For this purpose, X-band frequencies will be used for handling the thematic mapper (TM) and multispectral scanner (MSS) data streams. Those stations not equipped to receive X-band transmissions will be able to obtain only MSS data in real time using an S-band frequency, as have previous Landsat satellites. Table 1 lists the worldwide receiving stations for Landsat. Figure B-1 shows the ground receiving station MSS coverage as of August 1, 1982. The differences in area covered by each receiving station between Landsat 4 and the previous Landsat series of Satellites 1, 2, and 3 are a result of the different orbiting altitudes of the two systems. Landsat 1, 2, and 3 orbit the earth at an approximate altitude of 918 km, and the receiving station zone of coverage is indicated on Figure B-1 by the solid circle. Landsat 4 orbits the earth at approximately 705 km and hence has a smaller line of sight coverage, as indicated by the dashed circle on Figure B-1.

TABLE B-1

SUMMARY OF THE STATUS OF

LANDSAT RECEIVING STATIONS

Station Location	Distribution Center	DATA: DATE AVAILABLE (CCTs) MSS	RBV	TM
Argentina-Mar Chiquita	CNIE-Buenos Aires	1980	1981	1984
Australia-Alice Springs	ALS-Belconnan	1980		1985
Brazil-Cuiaba	INPE-Sao Paulo	1974	1981	1985
Canada-Prince Albert (Churchill)	CCRS-Ottawa	1972	1981	1982
Canada-Shoe Cove	CCRS-Ottawa	1977	1981	N/A
China	AS-Beijing	1984		1984
Italy-Fucino	ESA-Frascati	1976	1982	1983
Sweden-Kiruna	ESA-Frascati	1979		1983
Indonesia-Djakarta	Baksurtanal-Bojor	1983		1987
India-Hyderabad	NRSA-Andhra Pradesh	1980	1980	1983
Japan-Ohashi	RESTEC-Tokyo	1979	1981	1983
South Africa-Hartebeesthoek	NITR-Johannesburg	1980	1981	N/A
Thailand-Bangkok	NRC-Bangkok	1982		N/A
USA-Goldstone	EROS-Sioux Falls	1972	1980	N/A
USA-Greenbelt	EROS-Sioux Falls	1972	1980	1982
USA-Fairbanks	EROS-Sioux Falls	1972	1980	N/A
Upper Volta-Ouagadougou	CRTD	1984		1985

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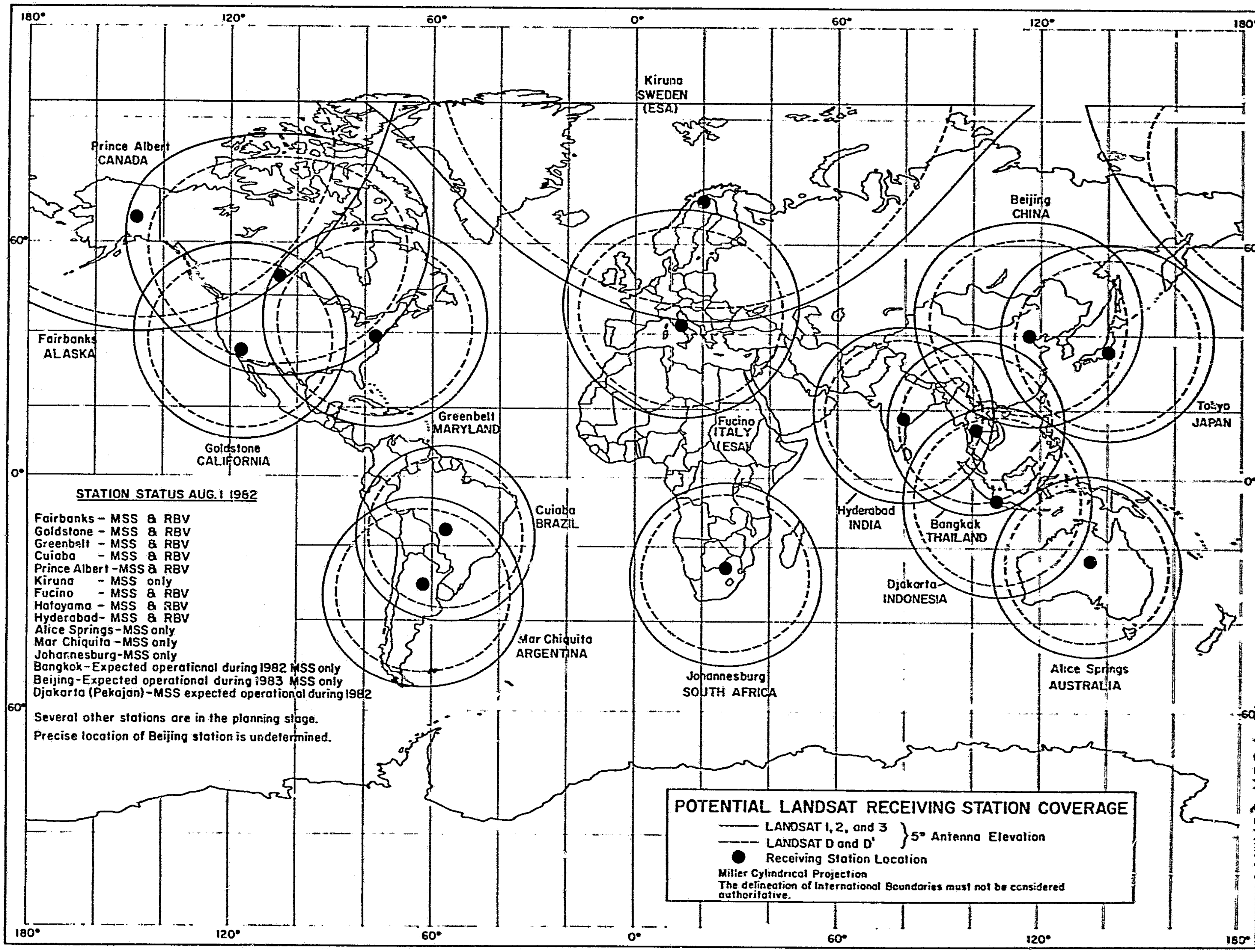


A number of features partly reflected by this figure include:

1. The second Canadian receiving station at Shoe Cove on the east coast will cease operations at the end of 1982. Coverage of Canada will continue from the Prince Albert station, which is scheduled for upgrading to receive Landsat 4 data in 1982.

2. The receiving station at Goldstone, California, will not be upgraded to receive thematic mapper (TM) data because the tracking and data relay satellite (TDRS) system will be operational in early 1983, which would be equal to the time required to upgrade the receiving station. TM and MSS data will be available for the western half of the United States at that time through the down-link at White Sands, New Mexico.

3. Three Asian ground receiving stations in Bangkok, Thailand; Djakarta, Indonesia; and Beijing, China expected to become operational in 1982 to 1983 are not anticipated at this date to upgrade their facilities to receive TM data. MSS data will be available from these stations using the same S-band frequency transmissions as the previous Landsat satellites.

At the time this report was written, only the receiving station at Goddard Space Flight Center possessed the facilities to receive TM data from Landsat 4. A number of foreign receiving stations have indicated their intention to upgrade their facilities to receive TM and MSS data. The current projected processing capabilities for these stations are summarized in Tables B-2 and B-3. The information contained in these two tables was supplied by NASA, represents the station status in October 1982.

The Landsat 4 satellite will also vary to its earlier counterparts in its capability to communicate with the tracking and data relay satellite (TDRS) system scheduled to begin deployment in 1983. The TDRS vehicles will relay data from the satellite to the earth in near real time, thus eliminating the need to rely upon on-board tape recorders, which have had limited lifetimes on previous satellites. The TDRS system will use Ku-band frequency transmissions to relay TM and MSS data simultaneously to a single ground receiving station at White Sands, New Mexico.

Figure B-2 illustrates the location of the TDRS down-link at White Sands, New Mexico, and the zone of exclusion, the region where Landsat 4 imagery will not be available due to the orbiting position of the TDRS system. When the ground receiving station in India (refer to Figure B-1) is upgraded to receive Landsat 4 TM data, most of this area excluded by the TDRS system will have available imagery. Currently, India will only be able to receive Landsat 4 MSS data using the standard S-band transmission frequency.

TABLE B-2

STATION PLANS FOR LANDSAT 4 MSS UPGRADE

Station	Receive and Record Capability	Processing Capability	Acquisition Requested
Australia	December 1982	June 1983	600 scenes/cycle (to cover all Australia plus some New Guinea; will be refined when quotas are known)
Argentina	Late 1982	Late 1982	200 scenes/cycle
Brazil	August 1982	August 1982	900 scenes/cycle (covers all South American land mass within range of Cuiaba Station)
Canada	August 1982	October 1982	Complete Canadian coverage
China	Late 1984	Late 1984	Approximately 450 scenes/cycle (to cover China)
ESA (2)	August 1982	December 1982 (Fucino)	1,750 ave. scenes/month (Fucino)
		January 1983 (Kiruna)	1,500 ave. (2,500 max.) scenes/month (Kiruna)
India	At launch	August 1982	Complete coverage of India
Indonesia	Mid-1983	Late 1983 or mid-1984	TBD
Japan	October 1982	December 1982	Complete coverage of Japan
South Africa	October 1982	October 1982	370 scenes/cycle
Thailand	Mid-1983	Late 1983	400 scenes/cycle
Zaire	TBD	TBD	TBD

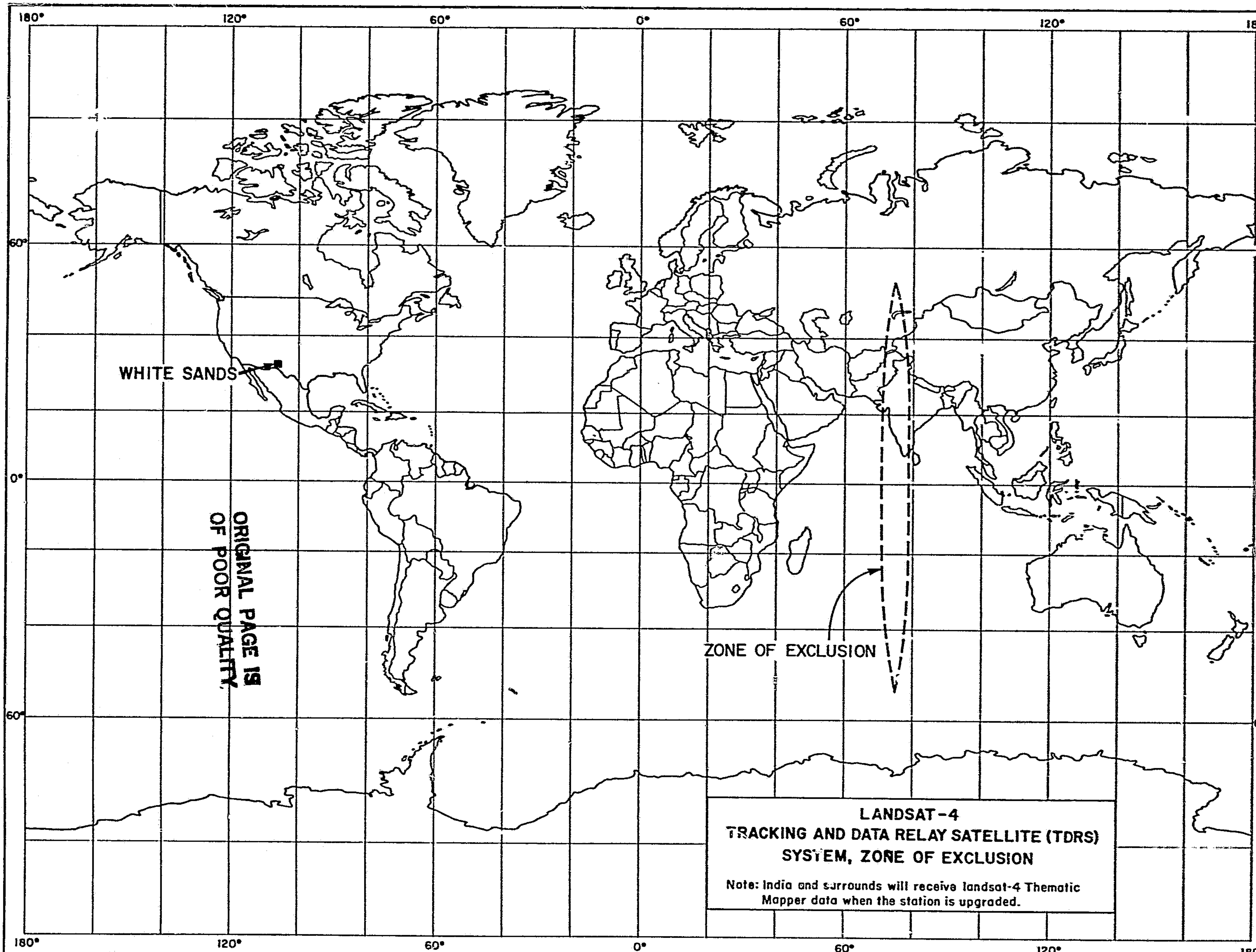
TABLE B-3

STATION PLANS FOR LANDSAT 4 TM RECEPTION AND PRODUCTS

LGSOWG Member	Reception Capability Date	Desired Acquisition Level	Operational Processing Date	PLANNED OUTPUT PRODUCTS: Type	Volume	Format
Australia	7-84	200 scenes/cycle	7-85	TBD	TBD	TBD
Argentina (CNIE)	Late 1983	200 scenes/cycle	Mid to late 1984	Film and CCT	5-6 scenes/day	TBD
Brazil (IPNE)	11-82	450 scenes/cycle	3-83	Bulk film product	-	Earth rotation corrected
				Quick-look film	5 scenes/day	System corrected
				CCT	2 scenes/week	Rad. corrected and geometric model included
			7-83	Bulk film product	20 scenes/day	System corrected
				Quick-look film	All data received	Earth rotation corrected (1 band)
				CCT	2 scenes/day	Rad. corrected and geometric model included
			7-84	Precision products	1 scene/day	System corrected and GCPs
Canada	10-82	6 scenes/day initially to increase to total coverage as soon as possible	12-82	Raw CCT	2 scenes/day	Scan line reversal only
			1-84	Film	5 scenes/day	3-band film, system corrected
				CCT	2 scenes/day	Bulk (system corrected), maybe BSQ, maybe subscene
			1-86	Film and CCT	25 subscenes/day	Geocoded precision processed

TABLE B-3 (CONTINUED)

LGSOWG Member	Reception Capability Date	Desired Acquisition Level	Operational Processing Date	PLANNED OUTPUT PRODUCTS Type	Volume	Format
China	Late 1984	10-20 scenes/day	Late 1984	Film and CCT	2 scenes/day (to increase)	TBD
ESA (2)	10-82	50 scenes/day	3-83	CCT	10 scenes/day (per facility)	Raw data
			Mid-1983	CCT	10 scenes/day (per facility)	System corrected
India	12-82	25-30 daytime, 10 nighttime scenes/cycle (12-82)	1-83 (preoperational)	Film	2-3 scenes/week	Bulk corrected film, scan line reversal only
		250 daytime, 150 nighttime scenes/cycle (1-83)	10-83 (operational)	Film and CCT	2 scenes/day	Bulk corrected film, scan line reversal only
Indonesia	Late 1983 to mid-1984	TBD	Late 1983 to mid-1984	CCT and film	TBD	TBD
Japan (NASDA)	3-83	Complete coverage of Japan	10-83	CCT and film	3-4 scenes/day	Bulk and precision corrected
South Africa	Late 1984	Complete Southern Africa coverage	Late 1984	CCT (6250) and film	1 scene/day	Bulk and precision corrected
Thailand	TBD	TBD	TBD	TBD	TBD	TBD
Zaire	TBD	TBD	TBD	TBD	TBD	TBD



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The information contained in this report can be considered current as of August 1982 but subject to revision in the near future. As noted previously, the Landsat Ground Receiving Station Operators Working Group meeting scheduled for October 1982 should provide an updated status of the foreign stations' commitment to upgrade their facilities to receive Landsat 4 data.

APPENDIX C

FUTURE NON-U.S. REMOTE SENSING SATELLITES

The U.S., although virtually alone in providing earth observational data in the 1970s, is being joined by a number of countries in the 1980s. These systems offer a potentially valuable complement to U.S. sensing systems. Planned programs include additional spectral bands, spectral ranges, spatial resolution, and times of coverage beyond those afforded by the U.S. program. Thus it is important to be aware of these programs and to know what data and data formats will be available.

The first major non-U.S. program is the French SPOT, scheduled for mid-1984. It offers two major features--high resolution and stereo. A third feature, yet to be evaluated, is the ability to sense off axis and thus to provide some measure of coping with cloud cover. A 20-m resolution in the visible band (0.5 to 0.89 um) in multispectral mode and a 10-m resolution in panchromatic mode are a significant opportunity for structural mapping relative to Landsat resolutions. The stereo capability likewise provides the opportunity for elevation data in areas for which such data do not currently exist or cannot be obtained.

This satellite will have on-board tape recorders such that worldwide imagery coverage will be available from the main ground receiving station at Toulouse, France. Table C-1 lists anticipated receiving stations, and Figure C-1 illustrates the potential receiving station coverage for line of sight communication with the SPOT satellite. Only the CNES facility at Toulouse, France, currently has a firm commitment to provide communication facilities to receive SPOT data. The remaining ground receiving stations that have expressed a desire to upgrade their facilities to receive SPOT data are shown in Figure C-3, with the dashed line representing the zone of coverage.

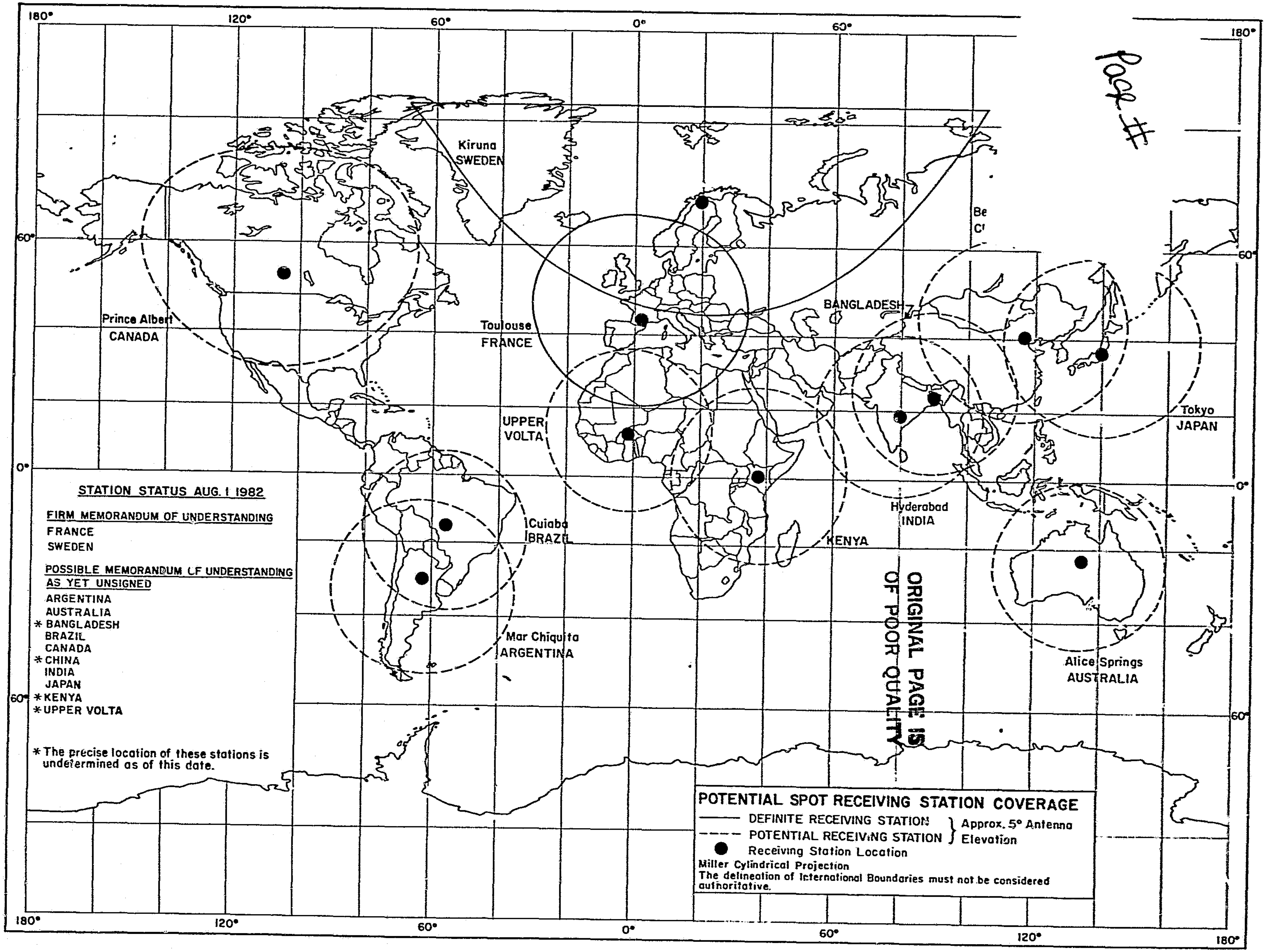
As of August 1982, only Bangladesh and Brazil have signed a memorandum of understanding with CNES, making a firm commitment to upgrade their receiving stations. Australia and Canada are currently considered close to signing a memorandum of understanding to upgrade their facilities. Three new receiving stations are being discussed to be built to receive SPOT data. These are located in Upper Volta, Kenya, and Bangladesh. Although the exact location of the station is unknown, these stations are shown on Figure C-3 in the center of the countries involved for diagrammatic purposes.

TABLE C-1

SUMMARY OF SPOT DATA RECEIVING STATIONS

Station Location	Distribution Center	First Date Data Could Be Available (CCTs)
Argentina-Mar Chiquita	CNIE-Buenos Aires	1986
Australia-Alice Springs	ALS-Belconnan	1985
Bangladesh	SPARRSO	1984
Brazil-Cuiaba	INPE-Sao Paulo	1984
Canada-Prince Albert	CCRS-Ottawa	1985
France-Toulouse	SPOTIMAGE-Paris	1984
India-Hyderabad	NRSA-Andhra Pradesh	1985
Japan-Ohashi	RESTEC-Tokyo	1985
South Africa-Hartebeesthoek	NITR-Johannesburg	
Upper Volta-Ouagadougou		1986

Distribution of spot data arranged through SPOTIMAGE.



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Other countries have remote sensing satellites in orbit or in the planning stage at this time. Table C-2 lists these systems and their projected launch dates. Table C-3 shows some of the sensor characteristics for these systems.

TABLE C-2

NON-U.S. REMOTE SENSING SATELLITE SYSTEMS

Country	Platform	Sensors	Estimated Launch Date
Canada	RADARSAT	SAR	1990
China	CHINASAT-12	SAR, MSS	1985
Europe	ERS-1	SAR, OCM, IMR	1986-1987
	ERSA	OII	1989
India	BHASKARA-1	TV camera	1979
	BHASKARA-2	TV camera	1981
	INSAT	MSS	1985
Japan	MOS-1	MESSR, VTIR	1985
	ERS-1	SAR, TM	1987
France	SPOT	HRV	1984
Russia	METEOR	MSU, FRAGMENT	1980

TABLE C-3

IMAGING SENSOR CHARACTERISTICS

Sensor	Wavelength (m)	IFOV (m)	SWATH (km)
RADARSAT	C-band	25-30	100
MOS-1			
MESSR	0.51-0.59, 0.61-0.69, 0.72-0.80	50	100
VTIR	6-7, 10.5-11.5, 11.5-12.5	2,600	500
METEOR			
MSU-E	0.5-0.7, 0.7-0.8, 0.8-1.0	30	30
MSU-SK	0.5-0.6, 0.6-0.7, 0.7-0.8, 0.8-1.0	170	600
FRAGMENT	0.7-1.1, 1.2-1.3, 1.5-1.8, 2.1-2.4	80	85
	0.4-0.8, 0.5-0.6, 0.6-0.7, 0.7-0.8		
ERS-1 (Japan)	SAR, TM		
ERS-1 (ESA)			
SAR		30	100
OCM	10 bands in 0.4-11.5		
ERSA (ESA)			
OII	6 bands in 0.52-2.35	30	175
	Pan	15	175
SPOT			
HRV	0.50-0.59, 0.61-0.68, 0.79-0.89	20	60
	Pan	10	60
CHINASAT-12			
MSS		80	NA

APPENDIX D

WHERE TO ORDER LANDSAT DATA WORLDWIDE

User Services Section
EROS Data Center
USGS
Sioux Falls, SD 57198
(615) 594-6151

Instituto de Pesquisas Espacias
Departmamento de Producao de Imagens
ATUS--Banco de Imagens Terrestres
Rodovia Presidente Dutra, Km 210
Cachoeira Paulista--CEP 12.630
Sao Paulo
BRAZIL
(0125) 611507

Canadian Centre for Remote Sensing (CCRS)
User Assistance & Marketing Unit
717 Belfast Road
Ottawa, Ontario K1A 0Y7
CANADA
(613) 995-1210

ESA--ESRIN
Earthnet User Services
Via Galileo Galilel
000 44 Frascati
ITALY
39-6-9401360 or 39-6-9401216

Remote Sensing Technology Center (RESTEC)
7-15-17 Roppongi, Minato-Ku
Tokyo 106
JAPAN
81-03-4031761

Director, National Remote Sensing Agency
No. 4 Sardar Petal Road
Hyderabad--500 003
Andhra Pradesh
INDIA
73839

Australian Landsat Station
14-16 Oatley Court
P. O. Box 28
Belconnan, ACT 2616
AUSTRALIA
062-515411

Comision Nacional de Investigaciones Espaciales (CNIE)
Centro de Procesamiento
Dorrego 4010
(1425) Buenos Aires
ARGENTINA
772 5108

Director, National Institute for Telecommunications Research
Attention Satellite Remote Sensing Centre
P. O. Box 3718
Johannesburg 2000
REPUBLIC OF SOUTH AFRICA
(12) 265271

Remote Sensing Division
National Research Council
Bangkok 9
THAILAND

Academia Sinica
Landsat Ground Station
Beijing
PEOPLE'S REPUBLIC OF CHINA
Telex 22474 ASCHL SIEVC

APPENDIX E

REMOTE SENSING DATA PROCESSING SYSTEM

Organizations responded to the Geosat Committee request for information on remote sensing data processing systems. Table F-1 lists the responders, and Table F-2 lists the significant parts of the systems. In some cases, a single organization had more than one system.

The purpose of this survey is to open the door for technical exchanges. However, at this point, we cannot list the system each organization has, since we gathered the information with a promise of anonymity.

TABLE E-1

ORGANIZATIONS RESPONDING TO GEOSAT SURVEY

ARCO
Plano, TX

Phillips Petroleum
Bartlesville, OK

Conoco Inc.
Ponca City, OK

Superior Oil
Houston, TX

Amoco Production Company (International)
Houston, TX

Chevron Oil Field Research
La Habra, CA

Tenneco Oil Exploration and Production
Houston, TX

Nielson Petroleum Information
Denver, CO

Bendix Field Engineering Corporation
Grand Junction, CO

British Petroleum
London UK

Spectral Africa
South Africa
Randfontein, Transvaal

Technicolor Government Services Inc.
Sioux Falls, SD

ESL Inc.
Sunnyvale, CA

Western Mining Corporation
Adelaide, Australia

Utah International
San Francisco, CA

ANMERCO
Melbourne, Australia

Cities Service
Tulsa, OK

Alcoa
Pittsburgh, PA

Bechtold Satellite Technology
Walnut, CA

Litton Aero Service
Houston, TX

Texasgulf Minerals Exploration
Golden, CO

GeoSpectra Corporation
Ann Arbor, MI

CRA Exploration Pty. Ltd.
Canberra, Australia

Billiton International Metals
The Hague, Netherlands

RADARSAT Project Office
Ottawa, Ontario

Columbia Gas System Service
Columbus, OH

Restec
Tokyo, Japan

Gulf Research and Development
Pittsburgh, PA

TABLE E-2

REMOTE SENSING HARDWARE SYSTEMS

REPORTED BY GEOSAT MEMBERS

Image display/processing	
No system	7
DeAnza 6400	5
I^2S Model 70	4
Comtal Vision One	3
Comtal Vision One/20	3
GE Image 100	2
Other	10
Image hard copy	
Optronics film writers (all models)	9
Matrix camera	5
Dunn camera	3
Applicon plotter	2
Other	4
Nothing	8
Computer systems	
Hewlett-Packard 3000	7
VAX 11/780	5
PDP 11/35	3
HP 1000	3
IBM 3033	3
IBM 4341	3
CDC 170/760	2
PDP 11/34	2
VAX 11/750	2
SEL 32/77	2
SEL 32/87	2
Other	11
Array processors	8
None	4
Image scanners	
Sierra video	2
Other Vidicon	3
Optronics C4100	1
Optronics C4500	3
Perkin-Elmer	1
None	18